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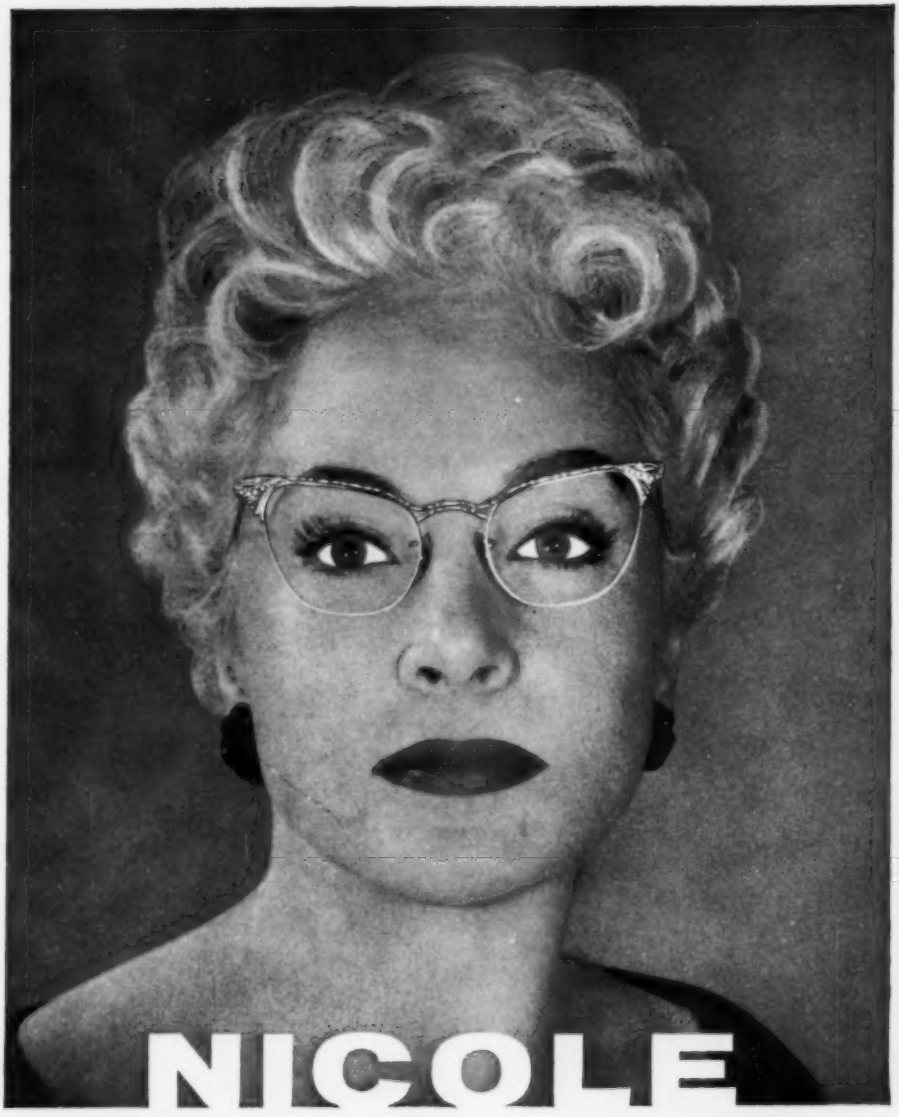

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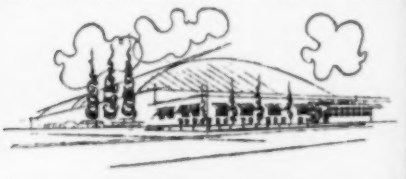

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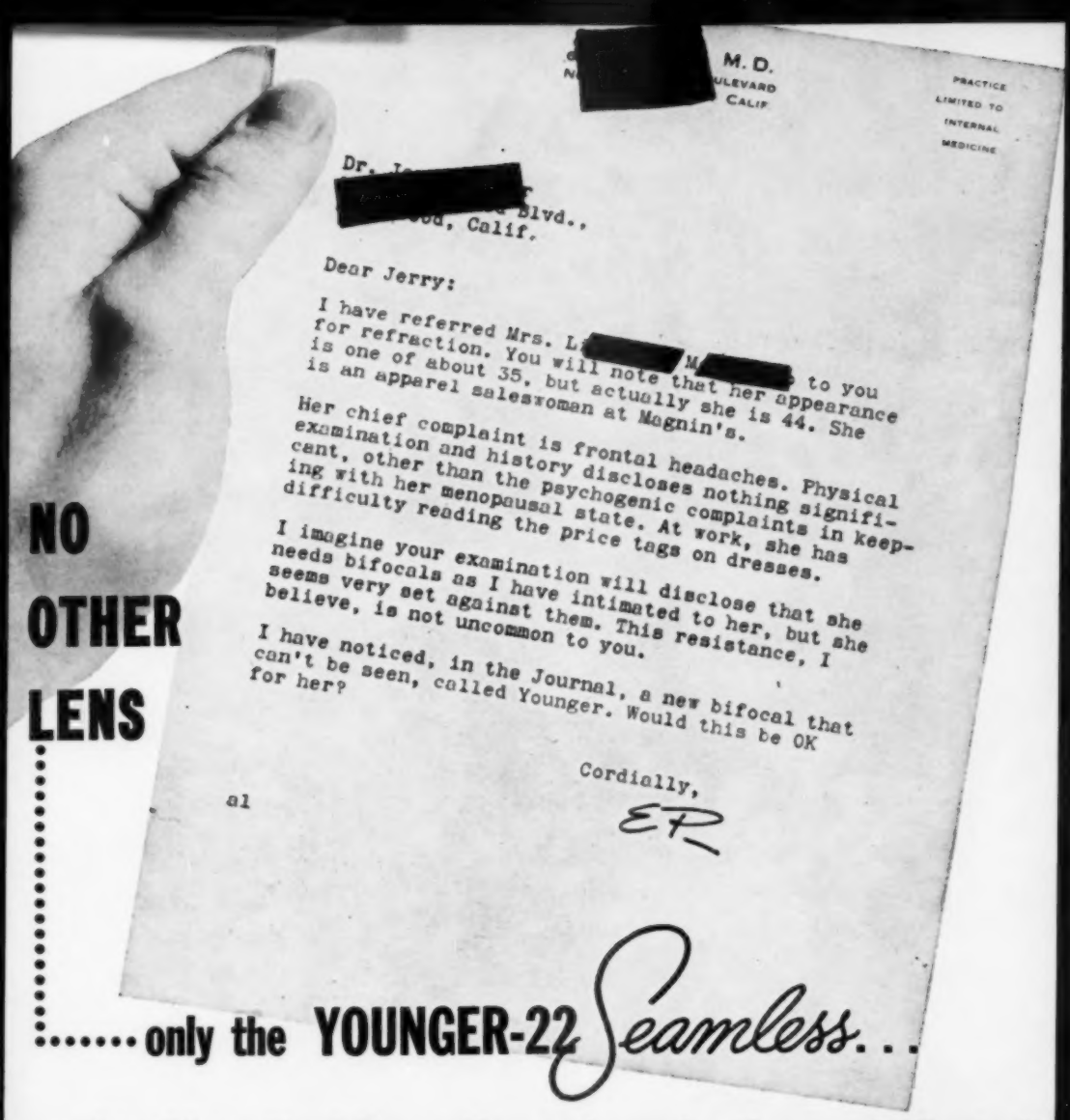
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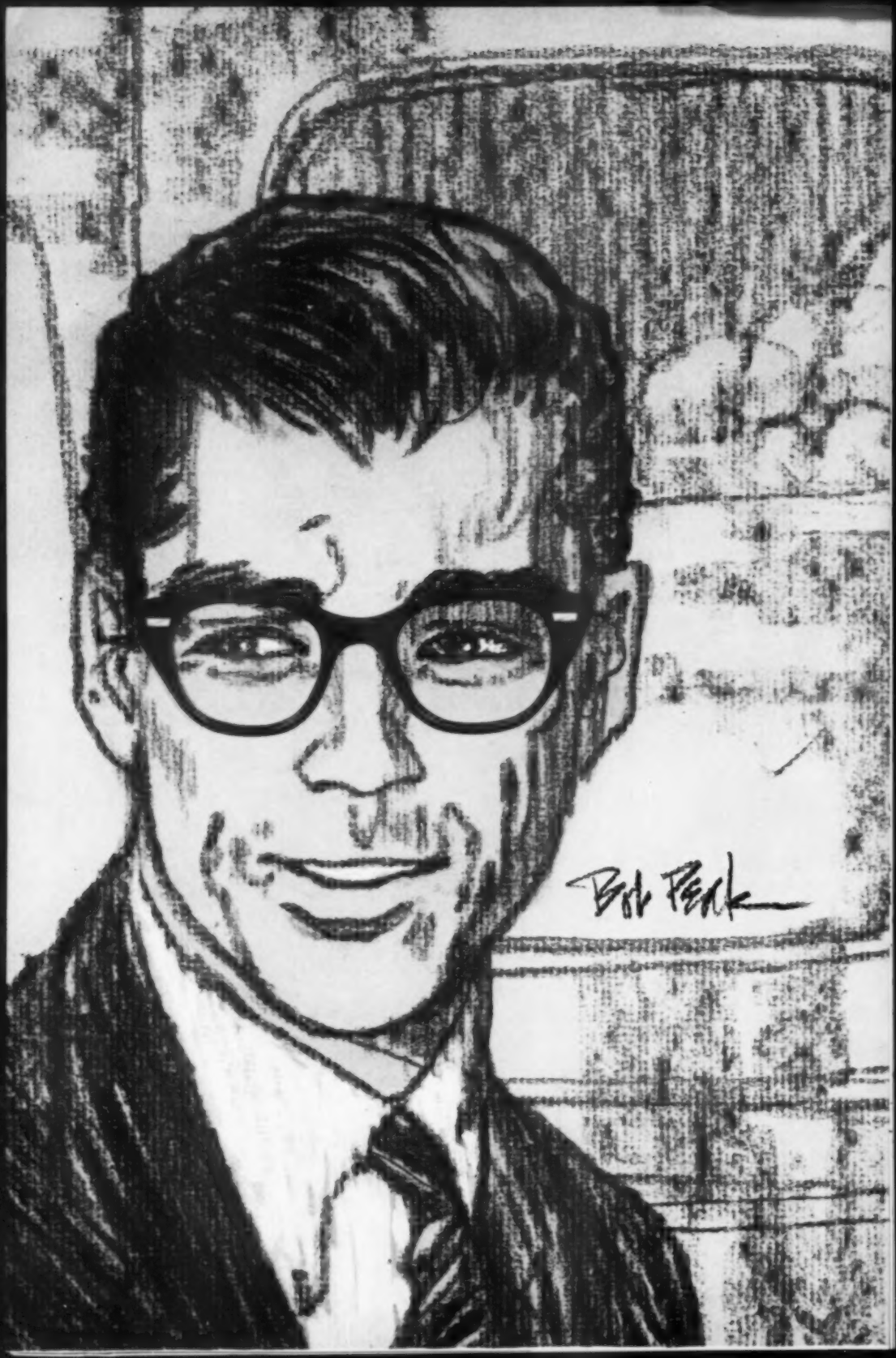
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Vol. 37 October, 1960 No. 10

THE EFFECT OF CHROMATIC ADAPTATION ON COLOR-BLIND OBSERVERS*

R. W. Bailey†
School of Optometry, The Ohio State University
Columbus, Ohio

INTRODUCTION

This study was carried out to find what color matches a color-blind observer will make after adaptation to chromatic stimuli. Matches were made during the recovery period from time = 0 to time = 16 seconds to provide a record of the changes which occur during this portion of the recovery period.

It appeared at the outset that protanopes and deuteranopes might yield data of considerable importance. These two types of color-blind subjects have no ability to differentiate between red and green: they apparently see blue, gray and yellow only.[1]

It would appear that color vision in such individuals depends upon two components[2] each of which involves an exciting substance subject to bright and dark adaptation. In the normal subject it is difficult to segregate the effect of these exciting substances from the effects of other exciting substances. But in the protanope and the deuteranope the blue and yellow responses are uncontaminated by other responses.

Chromatic adaptation might be used with the deuteranomalous observer to demonstrate the basis for the defect. The deuteranomalous observer requires more green in a red-green mixture than a normal observer to match a yellow, although his relative luminosity curve is nearly normal. It would appear from chromatic adaptation data obtained from normal individuals that it may be possible to render a normal individual deuteranomalous or a deuteranomalous individual normal, without producing any marked effects in the luminosity curve.

Rushton[3] has recently developed a method for measuring the bleaching of the foveal pigments and believes that this kind of information may help solve the riddles of color vision. It is important therefore to measure the time characteristics of chromatic adaptation to see what relation they bear to Rushton's data.

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*Submitted on February 23, 1960, for publication in the October, 1960, issue of the AMERICAN JOURNAL OF OPTOMETRY AND ARCHIVES OF AMERICAN ACADEMY OF OPTOMETRY.
This paper is based upon a thesis submitted in partial fulfillment of the requirements for the M.Sc. degree in Physiological Optics at the Ohio State University.
†Optometrist. Captain, M.S.C., U. S. Army. Now located at the Vision Branch of the U. S. Army Medical Laboratory, Fort Knox, Kentucky.

SUBJECTS

In order to carry out this study it has been necessary to locate deuteranopes, protanopes and deuteranomalous observers. Fortunately one of each has been found and has been available for the present study.

J.H., the deuteranope, is a 35 year old white male who has 20/20 acuity in each eye and has never worn spectacles. He is presently employed as a supervisor in the parts section of a local manufacturing firm. He has a family history of color-blindness. His maternal grandfather was color-blind. The grandfather had two daughters, the subject's mother and his aunt, each of whom had two sons. In each case one of the sons was color-blind, i.e., the observer and his cousin.

Observer J.L., the protanope, is a 36 year old white male serving in the armed forces. He has 20/20 acuity in each eye and has never worn spectacles. This subject can recall no family history of color-blindness, but is quite disturbed that this defect has heretofore prevented him from being commissioned in the armed forces.

Subjects J.H. and J.L. both failed the A.O. Pseudo-Isochromatic Plates and also made matches on an anomaloscope of yellow with either red or green.

The final determination of whether these two subjects were protanopic or deuteranopic was made by evaluation of their luminosity curves.

Observer R.W.B. is a 38 year old white male whose acuity is 20/15 for each eye. He was able to read only part of the A.O. Pseudo-Isochromatic Plates and made a deuteranomalous match of too much green when matching yellow on an anomaloscope. No history of color-blindness is available. Subsequent color-mixture data confirmed this classification.

LUMINOSITY DATA

Luminosity curves were determined for two normal observers B.W. and R.J.B., a deuteranomalous observer R.W.B., a protanope J.L. and a deuteranope J.H. These luminosity curves except for the protanope were obtained by flicker photometry.

Apparatus

The apparatus is a colorimeter, which has been designed by Fry and has been used in two previous studies.[4, 5] It consists of three monochromators utilizing 60° constant deviation type prisms (Wadsworth mounting) for dispersing systems (see Figure 1). These monochromators are referred to as Systems I, II and III and are so designated in Figure 1.

In order to obtain luminosity curves the mirror (55) and aperture

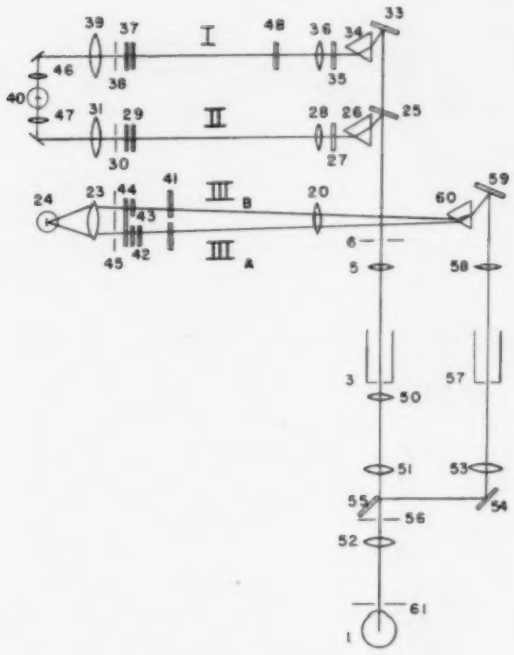

Fig. 1. Apparatus.

(56) were removed from the apparatus. The test stimulus is a circular patch bounded by the edge of the aperture in diaphragm (6) which is reimaged by lenses 5, 50 and 51 in the same plane previously occupied by aperture (56). It subtends a visual angle of 1.85°.

The source (24) is turned off and the aperture (6) is illuminated by Systems I and II both of which have a common source (40).

The ribbon tungsten filament lamp (40) is operated at 6V by means of a constant voltage power supply, the output of which was run through a 110V-6V transformer via a variac control. For calibration and subsequent data collection the output to lamp (40) was measured by a voltmeter in series with the lamp (40).

Lenses 46, 39 and 36 form an enlarged image of the ribbon filament (40) on the face of prism 34. Lenses 47, 31 and 28 play a similar role in System II.

Entrance slits for System I and II were 38 and 30. Crossed polaroids (29) were removed and the rotating polaroid (48) was also

removed. Crossed polaroids 37 were used to control the amount of flux in System I.

To reduce stray light from the unused portion of the spectrum, filters were inserted at 35. A blue-green filter (Corning 4308) was used for wavelengths 400 mμ to 600 mμ and a red filter (Corning 2418) was used for the range 600 mμ to 730 mμ. To eliminate infrared radiation two pieces of Libby Owens Ford heat absorbing glass 0.25 inches thick, and a water cell 1 cm. thick were introduced into the parallel beam between 6 and 5.

The common exit slit (3) was employed for both System I and II. It is 0.5 mm. wide and 2 mm. high. An image of the exit slit is formed by lenses 50, 51 and 52 at the center of the circular aperture (61) which is 2.9 mm. in diameter.

A neutral density filter was placed in System II between 27 and 28; and the prism-mirror unit (26 and 25) was adjusted to give a wavelength of 555 mμ for System II. The retinal irradiance produced by this beam was kept constant throughout the measurement of the luminosity curve.*

A variable-speed, rotating sector disc could be introduced so that the beams of Systems I and II from source 40 could be intercepted alternately. A flicker match was made possible by adjusting variable polaroid (37) and when necessary neutral density filters were added between 36 and 35. Flicker matches were made between the constant stimulus in System II and monochromatic stimuli in System I at 10 mμ intervals from 400 to 730 mμ.

Calibration

The procedure for calibrating the dispersing systems for wavelength has been previously described by Fry.[6]

A Reeder thermocouple having a sensitivity of 8 microvolts per microwatt was used to calibrate the colorimeter in terms of energy output of System I as a function of wavelength. This thermocouple was assumed to be a non-selective absorber and was positioned by means of an adapter so that the exit slit[3] was focused by lenses 50, 51 and 52 upon the receiver area of the thermocouple. The eyepiece containing the circular aperture (61) had to be removed. A mechanical chopper-and-rectifier assembly, operating at 13 cycles per second, was positioned so that the chopper was located between 3 and 50 to chop the beam from System I before it reached the thermocouple at 61. The output of the

*For a normal subject this 555 mμ stimulus was found to correspond to a retinal illuminance of 53.5 photons when compared to a Macbeth Illuminometer standard source. It has been assumed that this value holds for all subjects. The retinal illuminance values for other stimuli have been assessed relative to a 555 mμ stimulus.

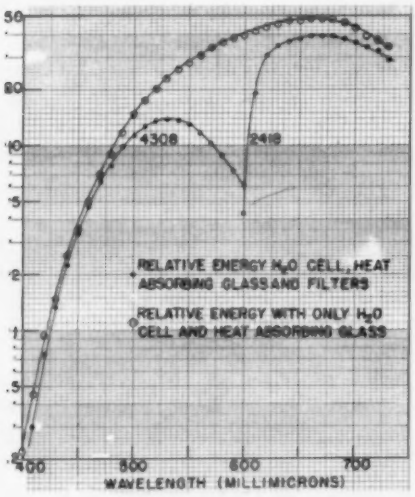

Fig. 2. Relative energy curves for the test stimuli.

thermocouple was pre-amplified and then fed into a Perkin-Elmer M-107, 13 cycle AC amplifier. The amplifier output was then fed

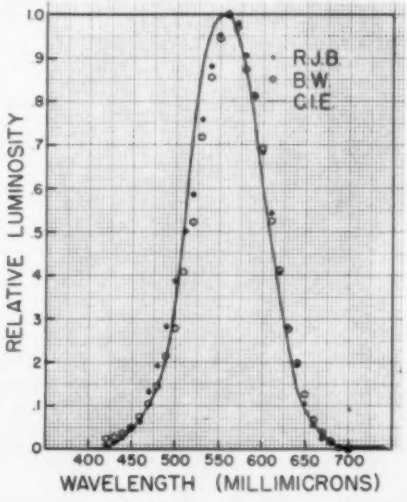

Fig. 3. Luminosity curves for two normal subjects B.W. and R.J.B. and for the CIE standard observer.

into a Leeds and Northrup 10 microwatt recorder which made a record of the output of the system.*

The output of the thermocouple was recorded throughout the range 400-730 mμ for a period of one minute at each 10 mμ. The results are plotted in Figure 2. During these measurements the crossed polaroid (37) was set for maximum transmission and no neutral filters were used between 35 and 36.

Measurements

Using the flicker technique measurements were made of the relative retinal irradiance for the different wavelengths required to produce the same brightness as a constant standard stimulus having a wavelength of 555 mμ. From these data the relative luminosity of the different parts of the spectrum was computed.

Figure 3 is a comparison of the luminosity curves of normal observers R.J.B. and B.W. with the CIE data. In that the variations are within the limits expected as a result of individual differences, this constitutes a check on the validity of the calibration technique. Figure 4 shows the relative luminosity data for subjects J.H., J.L. and R.W.B. The data for subjects J.H. and R.W.B. were obtained by flicker pho-

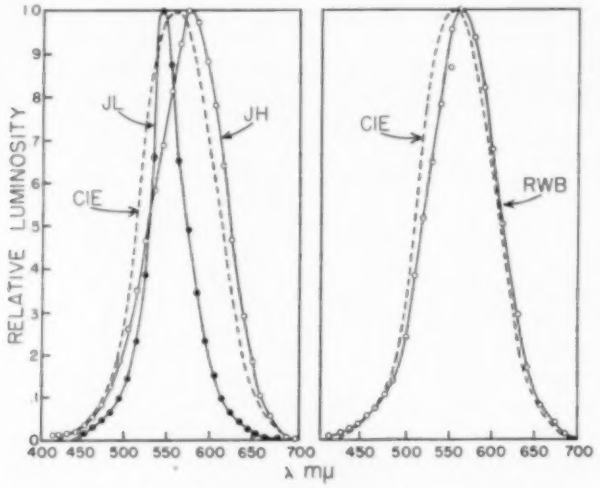

Fig. 4. Luminosity curves for a protanope (J.L.), a deuteranope (J.H.), a deuteranomalous observer (R.W.B.) and the CIE standard observer.

*The author is indebted to Dr. Ely Bell, Physics Department, The Ohio State University, for arranging the loan of the calibration equipment.

Fig. 5. Bipartite test pattern. It subtends a visual angle of 2.34°.

tometry. The data for subject J.L. were obtained by a method to be described later.

The luminosity curves for R.W.B. and J.H. are characteristic of those found in deuteranomalous and deuteranopic observers. The luminosity curve for J.L. is characteristic of those found for protanomalous and protanopic observers.

COLOR MIXTURE DATA FOR THE DICHROMATS

In order to confirm the anomaloscope finding that J.H. and J.L. are dichromats it is necessary to demonstrate that all the colors of the spectrum can be matched by two monochromatic stimuli. In acquiring these data one can obtain also the differences in sensitivity to chromaticity which can be used in evaluating the adaptation data to be described later.

For subject J.H. the apparatus was arranged as shown in Figure 1. The crossed polaroids (29), the aperture (6) and the rotating polaroid (48) were removed. This provides a bipartite field (see Fig. 5), the

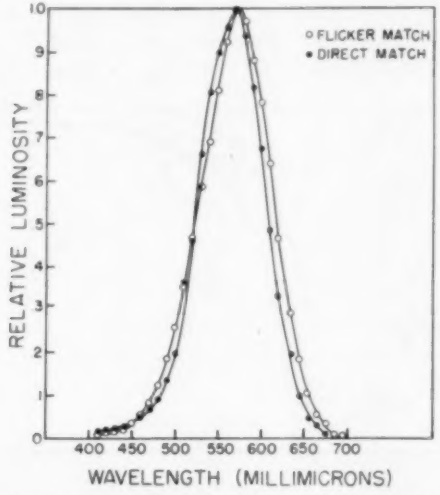

Fig. 6. Luminosity curves for J.H. obtained by flicker and direct matching.

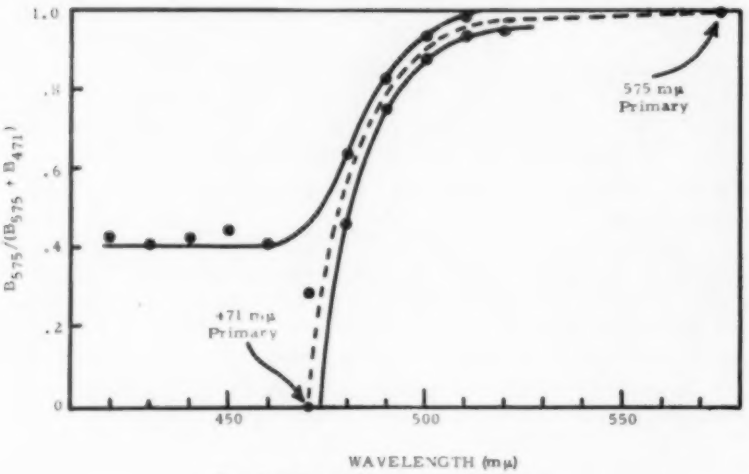

Fig. 7. Color mixture data for J.H.

boundary of which corresponds to aperture (56). It subtends a visual angle of 2.34°. The dividing line is formed by the edge of the first surface mirror (55). The lenses 50, 51, 52 and 53 form images of the exit slits 3 and 57, at the center of the circular aperture (61). The right half of the field is illuminated by System I and the left half by System III. System III was adjusted to provide a mixture of 575 mμ and 471 mμ, which could be varied without changing the brightness. It is neces-

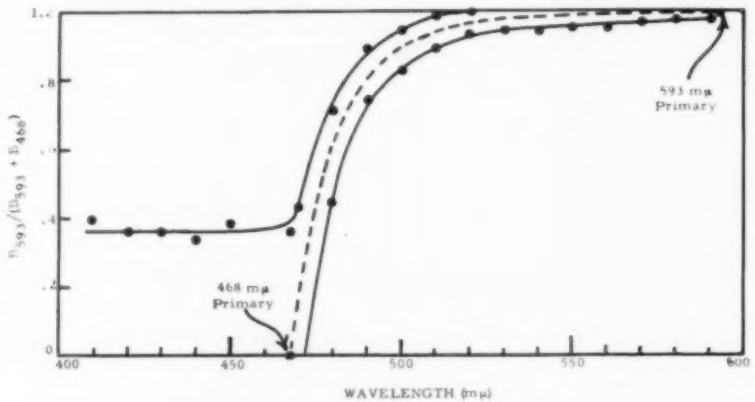

Fig. 8. Color mixture data for J.L.

sary, however, for the subject being tested to adjust ahead of time the variac controlling source (24) and the rotating polaroid (42) to make the two primaries in System III produce the same retinal illuminance when the crossed polaroids (43 and 44) are adjusted so that the transmittance for each beam is 50 per cent of the maximum. Each beam when set at its maximum matches in brightness the standard 555 mμ stimulus from System II. This mixture of 575 mμ and 471 mμ can be compared in color and brightness with the monochromatic stimuli provided by System I. The luminance of each monochromatic stimulus was varied to make the match in brightness. This was repeated five times for each wavelength. The relative retinal irradiance values for the beam from System I required for a brightness match have been used to determine the relative luminosity curve for J.H. (Fig. 6). The curve for J.H. determined by flicker photometry is also shown in Figure 6. The agreement is good enough to justify this method of acquiring luminosity data.

In making the match the range of matching mixtures of 575 mμ and 471 mμ was determined for each of the various monochromatic stimuli and the results are shown in Figure 7. Each of the points representing the limits of the range is an average of five settings.

The same procedure was followed with subject J.L., except that a

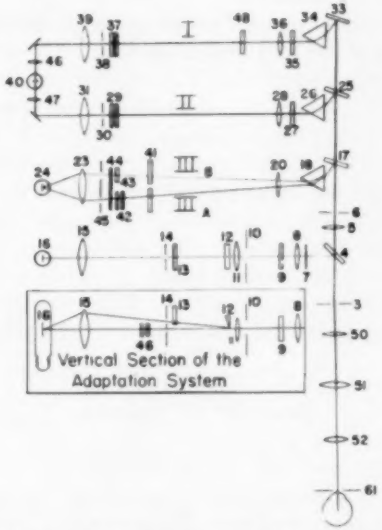

Fig. 9. Modification of the apparatus for adaptation studies.

different set of primaries were used, namely, 593 mμ and 468 mμ. The luminosity curve data for this observer were also determined at the same time by recording an average of five brightness matches of System III and System I. The luminosity data for J.L. are shown in Figure 5 and the color mixture data in Figure 8.

The technique described above for acquiring data has the advantage that color mixture coefficients, wavelength discrimination data and luminosity data can be obtained in one operation. It is to be noted in Figures 7 and 8 that the data may be used to extract wavelength discrimination data. According to Fry[7] it is more meaningful to leave the data expressed in terms of limits of matching mixtures. In analyzing the data one can start with the curves which represent the limits of matching mixtures. The dotted curve has been drawn so that the vertical separation between the dotted curve and the upper limit is the same as the vertical separation between the lower limit and the dotted curve. The dotted curve must pass through zero at the blue primary and through 1.0 at the yellow primary.

One can take the lateral displacement of one of the limiting lines from the dotted line as a measure of wavelength discrimination.

The data definitely demonstrate that J.H. and J.L. are dichromats and therefore are satisfactory subjects for chromatic adaptation experiments designed for dichromats.

One difficulty that appeared at the outset is that chromaticity discrimination is poor at the blue end of the scale.

ADAPTATION

The apparatus used in the adaptation experiments has been previously described by Fry[4] and is illustrated in Figure 9. The only modification is that in Fry's original paper it was proposed that the eye be placed at exit slit (3) instead of behind the aperture (61).

When the mirror (4) is positioned as indicated, the shutter at 7 is open and the subject is allowed to view the adaptation stimulus. The adaptation stimulus is an inverted image of the circular aperture (10) which is formed by the lenses 8, 50 and 51 between 51 and 52. This stimulus is split into upper and lower halves by the base-up prism (12)

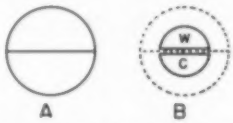

Fig. 10. Stimulus patterns for the adaptation experiments. The test stimuli C and W are segments of a disk 1.85° in diameter. The gap is 0.52° wide. The adaptation stimulus (A) is 8.35° in diameter.

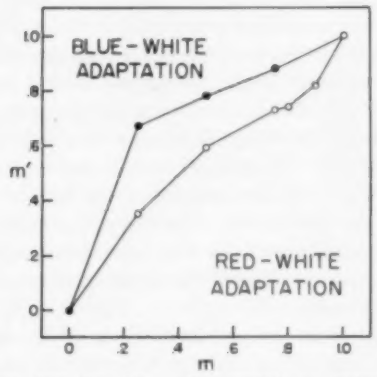

Fig. 11. Adaptation data for J.L. The symbol m designates the ratio $B_{593}/(B_{593} + B_{468})$ for stimulus C and the symbol m′ is the corresponding value for stimulus W.

which covers the upper half of aperture 10. The adaptation stimulus may be described therefore as a bipartite field with a horizontal dividing line as shown in Fig. 10A.

The upper and lower halves of the central region of the retina are differentially adapted by allowing the eye to fixate a point on the dividing line of the bipartite field (see Fig. 10A). The lower half is illuminated with red or blue light and the upper half with white light. The red stimulus represents light from a 100 watt daylight incandescent

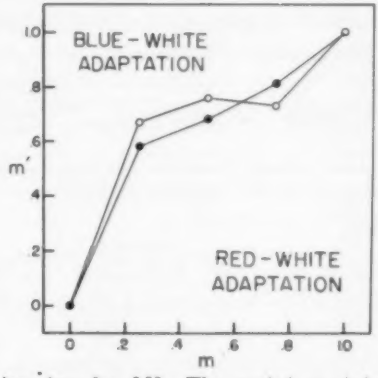

Fig. 12. Adaptation data for J.H. The symbol m designates the ratio $B_{575}/(B_{575} + B_{471})$ for stimulus C and the symbol m′ designates the corresponding value for stimulus W.

lamp (16) transmitted through a 2418 Corning filter (13). To obtain blue light a 5543 Corning filter was used. The retinal illuminances produced in a normal eye by the red and blue stimuli were 4250 and 2262 trolands respectively. Each was paired with a white adaptation stimulus which each subject adjusted to make it equal in brightness to the colored stimulus. The white light comes also from the source at 16 and is passed through the pair of crossed polaroids at 46.

The mirror (4) can be rotated out of the line of view and simultaneously the shutter (7) closes. The subject can then view the test stimuli (C and W) in Figure 10B which are formed by apertures in a diaphragm at 6. An inverted image of these apertures is formed by the lenses 5, 50 and 51 between 51 and 52. The mirror (4) and shutter (7) are both controlled by a single hand lever which is operated by the experimenter. The adaptation and the test stimuli are centered on the same line of sight so that in changing from the adaptation stimuli to the test stimuli, no change in direction of fixation is required. The eye is permitted to fixate a point midway between the two test patches. The lower opening in the diaphragm (6) is covered by the mirror (17) which reflects light from Systems IIIA and IIIB. The upper opening transmits light from Systems I and II.

Each of the two test stimuli is a mixture of the same two monochromatic stimuli. When the luminance controls have been properly adjusted the ratio of the two components in each mixture can be varied without affecting the luminance of the combination. This luminance is equal to that of the standard 555 mμ stimulus which produces a retinal illuminance of 53.5 trolands in a normal observer.

In the usual situation the adaptation stimuli and test stimuli alter-

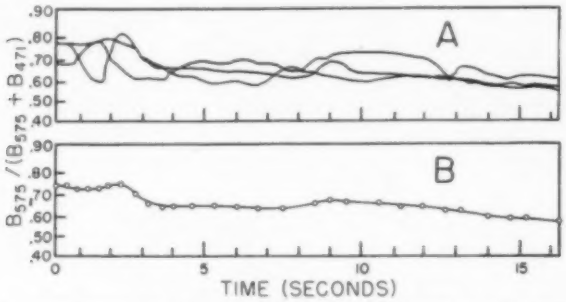

Fig. 13. Recovery curves for J.L. following white-blue adaptation. The curve in graph B is the average of the three curves in graph A. The ordinate represents the ratio $B_{575}/(B_{575}+B_{471})$ for stimulus W required to match stimulus C which has a fixed ratio of 0.5.

nate with each other, four seconds being allowed for the test stimuli and ten for the adaptation stimuli. The subject can adjust the mixture for W while W and C are being viewed or during the adaptation periods, but the final setting must be one in which the two test stimuli appear alike at the beginning of the test period.

The effect of red and white and of blue and white adaptation on the protanope (J.L.) and the deuteranope (J.H.) are shown in Figure 11 and Figure 12. The effect of blue and white adaptation is to make a blue-yellow mixture appear yellower to blue-adapted retina than to white-adapted retina. However, the red adaption effects on the protanope (J.L.) were about the same as the white adaptation effects. In the deuteranope (J.H.) red adaptation produces the same kind of effect as blue. This comes as a surprise and merits further study, but time was not available for further experiments.

The recovery curve for the protanope (J.L.) after blue and white adaptation, from zero to sixteen seconds, is shown in Figure 13. This was obtained by fastening a mechanical recorder to the shaft controlling polaroid (44). Recovery records following red and white, and blue and white adaptation of deuteranope J.H. are shown in Figure 14. These data help to substantiate the adaptation data shown in Figure 11 in that the effect of the red adaptation is stronger than blue and in the same direction.

The irregularities in the recovery curves for J.L. are dependent upon the confusion as to the direction in which to turn the knob to restore a match. After considerable practice with the knob a subject can turn out smooth curves such as those turned out by J.H. in Figure 14.

Sixteen seconds is not long enough to recover from chromatic adaptation. The curves probably should be traced for over a minute.

Data for the Deuteranomalous Observer

Of primary interest in the case of a deuteranomalous observer is

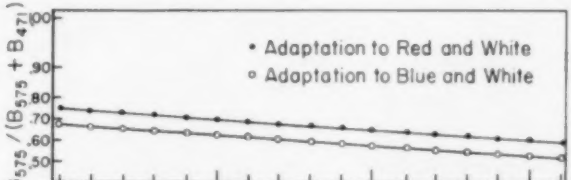

Fig. 14. Recovery curves for J.H. following white-red and white-blue adaptation. The ordinate represents the ratio for W required to match C which has a fixed ratio of 0.5.

the mixture of red and green required to match a yellow. The mixture data for the anomalous trichromatic observer were determined with the same arrangement used for dichromats, but the primaries were 688 mμ and 525 mμ. The mixture data for wavelengths between 688 mμ and 525 mμ are shown in Figure 15. No depurification of the test stimulus with blue was required for a complete match. Similar mixture data for two normal subjects R.J.B. and G.A.F. are included in the graph.

Mixtures of 525 mμ and 688 mμ applied to white-adapted retina were also compared to the same mixtures applied to the green- and red-adapted retina. The results are shown in Figure 16. From the results of red adaptation shown in Figure 16 it can be determined how red adaptation would effect the mixture data in Figure 15. The dashed curve represents the mixture data after adaptation based upon the results shown in Figure 16. It is obvious from this that one can convert a deuter-anomalous observer to a normal observer by red adaptation. An attempt was made to shed some light on the underlying mechanism by tracing the recovery from red adaptation. An average recovery curve is shown in Figure 17.

The effect of red adaptation on the luminosity curve of R.J.B. was measured. The apparatus was arranged as shown in Figure 2 except that

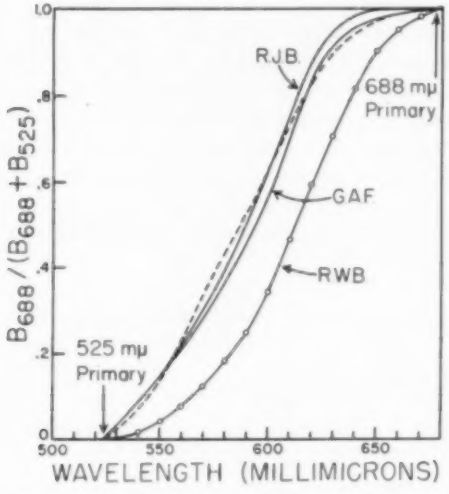

Fig. 15. Mixture data for R.W.B. before and after (dashed line) adaptation to a red-white adaptation stimulus. Mixture data from two normals G.A.F. and R.J.B. are included for comparison.

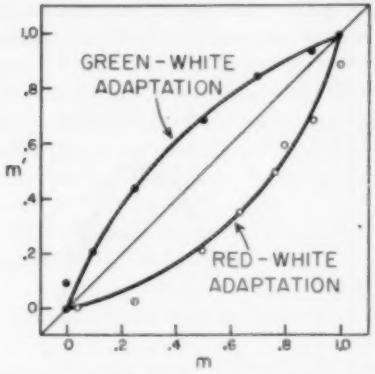

Fig. 16. Adaptation data for R.W.B. The symbol m designates the ratio $B_{668}/(B_{668} + B_{525})$ for stimulus C and m′ designates the matching ratio for stimulus W. The retinal illuminances produced by the red and green adaptation stimuli as measured by a normal observer were 4250 and 7700 trolands, respectively. The white adaptation stimulus was adjusted by the subject to be equal in brightness to the colored stimulus. Corning filters 2418 and 4010 were used at 13 to obtain red and green stimuli, respectively.

the mirror-prism unit (17 and 18) was removed and a circular aperture was used at (6). This subtended a visual angle of 1.85°. The prism (12) was removed to make both halves of the adaptation stimulus red. The luminance of the adaptation stimulus as measured by a normal subject was found to be 4250 photons.

Prior to presenting the adaptation stimulus a series of five flicker matches were made between the test stimulus in System I and the standard 555 mμ stimulus in System II. The adaptation stimulus was then presented for 10 seconds and then four seconds was allowed for making a flicker match between the monochromatic test stimulus in System I with the standard 555 mμ stimulus in System II. Several cycles were

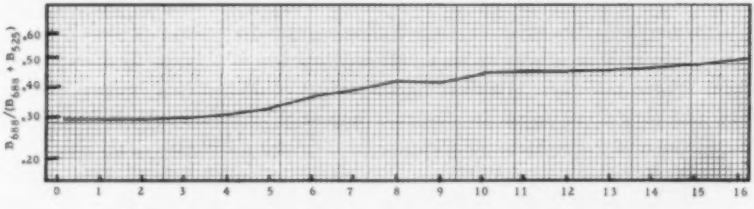

Fig. 17. Recovery curve for R.W.B. following red-white adaptation. The ordinate for R.W.B. represents the ratio for W required to match C which has a fixed ratio of 0.5.

required to make the match and five of such matches were made at 10 mμ intervals. Time was allowed for dark adaptation before starting each new stimulus.

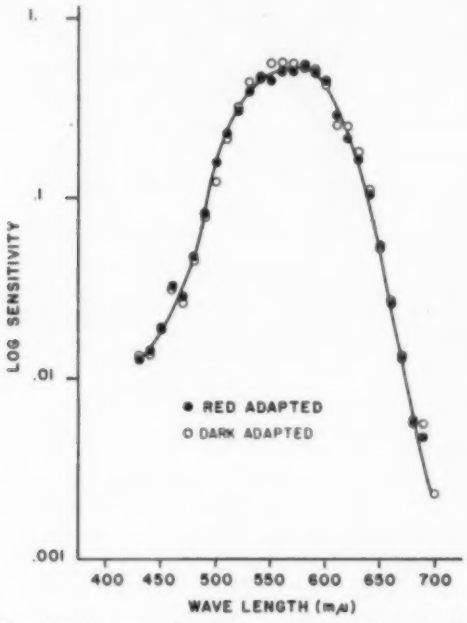

Fig. 18. Luminosity curves for a dark adapted and a red adapted retina.

The data are plotted in Figure 18. The differences between the two sets of data are probably not significant and the two sets have been fitted with a single curve which is the same as for R.W.B. in Figure 6. One may conclude from this that the two mechanisms involved in chromatic adaptation which are differentially affected by red and green adaptation, do not appear to be responsible for the brightness response. It is difficult to reconcile this finding with Rushton's[3] absorption data for the foveal pigments in deuteranopes and normals, which according to his analysis appear to be related to luminosity and chromaticity.

CONCLUSIONS

It has been demonstrated that chromatic adaptation may be used for the deuteranomalous observer, R.W.B., to render the color mixture data normal. On the other hand the effect of red adaptation on the luminosity curve is almost negligible.

The chromatic adaptation effects upon the dichromats, protanope J.L. and deuteranope J.H. are difficult to interpret. The blue adapted retina sees a blue-yellow mixture to be yellower than the white adapted retina as might be expected. But the red adapted retina of a deuteranope also sees a blue-yellow mixture yellower than the white adapted retina. It was to be expected that the mixture would appear less yellow, because a red stimulus to a deuteranope should be the same as a yellow stimulus, and yellow adaptation should leave the observer less sensitive to yellow.

No attempt has been made to locate the fundamental stimuli on the color mixture scales of the dichromats.

The method of acquiring mixture data for a dichromat has been modified to yield sufficient information to derive a luminosity curve. Also wavelength discrimination curves are unnecessary when this method of analysis is employed. In Figures 6 and 7 the discrimination zone in terms of wavelength is represented by the horizontal distance between the two lines representing the limits of matching mixtures.

The effect of blue or yellow adaptation on a blue-yellow mixture in a protanope or deuteranope probably involves a different mechanism than the effect of red or green adaptation on a red-green mixture in a deuteranomalous observer, and it was hoped that data on rates of recovery might throw light on this difference, but the data are not precise enough nor extensive enough to permit any major conclusions to be drawn.

The rates of recovery from chromatic adaptation appear much more rapid than the recovery from bleaching reported by Rushton[3] and hence the pigments investigated by him are probably not involved in the rapid changes in chromatic adaptation. It must be admitted, however, that bleaching stimuli are much stronger than the chromatic adaptation stimuli and the possibility of some connection should not be ruled out.

ACKNOWLEDGMENTS

The author is indebted to Dr. Glenn A. Fry who served as his graduate advisor and who contributed helpful suggestions and assistance in planning and completing the experiments.

Appreciation is also expressed to the Office of the Surgeon General, U. S. Army, for the opportunity to engage in graduate work.

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INSTRUMENT REVIEW

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Fig. 1

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ON THE RELATIONSHIP BETWEEN ACCOMMODATION AND ACCOMMODATIVE CONVERGENCE*

PART II. STABILITY

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School of Optometry, University of California
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The notion that the AC/A ratio is stable[1-3] has been challenged recently by reports[4-9] of variation in measured values of this visual function. Thus, the issue seems not to be, "Is the AC/A ratio stable?", but rather, "What is the degree and nature of its instability?". The limited evidence available and the importance of the question justify experimental re-examination. The following factors might be expected to influence the stability of the AC/A ratio: 1) random error of measurement, 2) biological variation, 3) practice effects, 4) environmental factors, 5) orthoptic training, and 6) increasing age. The present paper is concerned with the first four of these factors as they apply to weekly retesting during a nine-week interval; a subsequent paper[10] will consider the influence of orthoptic training.

The subjects were four optometry students with some experience in psychophysical experiments. The experimental procedure consisted of measuring the AC/A ratio with a refractor and with a haploscope and has been described previously.[11] For both methods the accommodative stimuli were presented to the right eye in the following order: 0.0, 2.5, 1.5, and 3.5 D. Measurements were taken with any ametropia corrected.

RESULTS

The haploscope data from each trial were plotted in two ways. In one plot the ordinate was the accommodative *stimulus*, in the other it was the accommodative *response;* in both, the abscissa represented accommodative convergence. The refractor data were plotted with accommodative stimulus versus accommodative convergence. As reported previously[11] the haploscope response data with their two dependent variables were fitted to a straight line by the method of Madansky;[12] ordinary regression methods were used for the stimulus data. The

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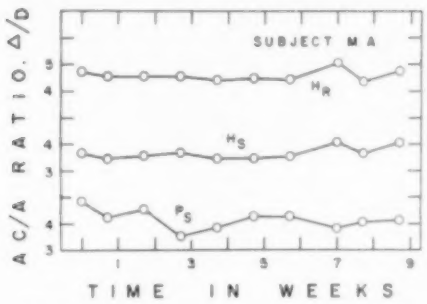

Figs. 1 through 4. AC/A ratio plotted as a function of time. Measurements based on accommodative response data with haploscope (H_R), accommodative stimulus data with haploscope (H_S), and accommodative stimulus data with refractor using a Risley prism (P_S). Each circle represents the reciprocal of the slope of the straight line fitted by least squares to twenty data points over an accommodative range of 0 to 3.5 D.

reciprocal of the slope of the line was taken as the measure of the AC/A ratio in Δ/D. An additional AC/A ratio was calculated from the clinical data using only two accommodative stimuli, 0.0 and 2.5 D., according to the formula $200\ a + b_n\ (P_a - P_o)$ where the interpupillary distance, 2a, and the near fixation distance, b_n, are in meters and the lateral phorias at near, P_n, and at distance, P_o, are in prism diopters (esophoria is considered positive).

Figures 1 through 4 show the AC/A ratio for the four subjects over an interval of about nine weeks. The standard deviations of the AC/A ratios for four methods are presented in Table I. It is seen that the standard deviations for the haploscopically determined AC/A ratios are smaller than those for the clinically obtained values, having an average value of about 0.12 Δ as compared with about 0.18 Δ. The variance

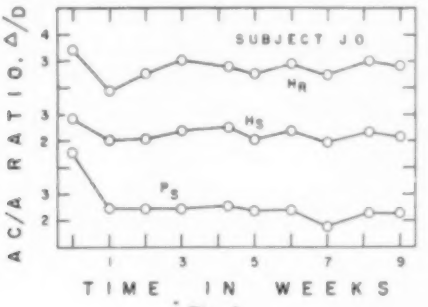

Fig. 2

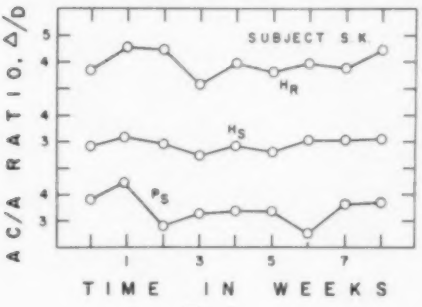

Fig. 3

of the haploscope stimulus data is seen to be generally smaller than the haploscope response and refractor data; in four instances this difference is significant by the F-test.

The time interval during which experimental data were obtained was divided into two equal or nearly equal parts. For subjects having ten trials, each sub-interval contained five trials; for those with nine trials, the first sub-interval had five trials, the second had four. The mean AC/A ratios for the two sub-intervals are given in Table II. The largest change was a decrease of 0.68 Δ in the refractor AC/A ratio for subject J.O. It is interesting that for this same subject there was virtually no change observed in the haploscope response AC/A ratio.

A more satisfactory method of testing for a change in AC/A ratio with time is to calculate the Spearman rank correlation (r_s) between AC/A ratio and trial number. It is seen in Table III that only one subject, J.O., has a statistically significant rank correlation (—0.88 and —0.59), indicating a trend of decrease in the clinically measured AC/A ratio from trial to trial. For this same subject the r_s values for the haplo-

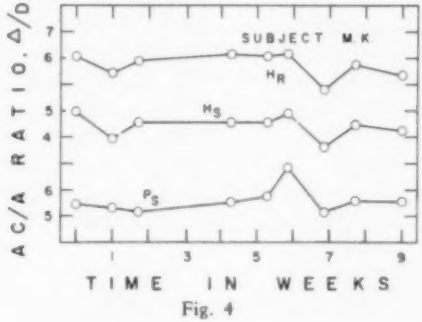

Fig. 4

TABLE I
Standard Deviation of AC/A Ratios

Method	Subjects M.A. n = 10	J.O. n = 10	S.K. n = 9	M.K. n = 9
Haploscope, response	.07	.13	.16	.15
Haploscope, stimulus	.07	.09	.08	.14
Risley Prism, stimulus, 4 levels	.12	.24**	.19*	.17
Risley Prism, stimulus, 2 levels	.15*	.18	.17*	.21

Asterisk indicates variance (S.D.^{2}) is significantly different from variance of haploscope stimulus AC/A ratio by F-test at 5% level: double asterisk indicates significance at 1% level.

TABLE II
Change in AC/A ratio during experimental interval

Subject	Method	Mean AC/A Ratio, First Half	Second Half	Δ/D Change in AC/A
M.A.	haploscope	4.57	4.62	+0.05
	refractor	4.21	4.12	—0.09
J.O.	haploscope	2.73	2.74	+0.01
	refractor	2.89	2.21	—0.68
S.K.	haploscope	3.97	3.96	—0.01
	refractor	3.55	3.32	—0.23
M.K.	haploscope	5.93	5.52	—0.41
	refractor	5.44	5.79	+0.35

scopically obtained AC/A ratios were not statistically significant. Of the sixteen rank correlations listed in Table III, twelve are negative (suggesting a decrease in AC/A ratio with time) and four are positive: this proportion of negative correlations is not significant since such a proportion would be expected to occur by chance in samples from an equally divided population as often as 10 per cent of the time.

The Spearman rank correlation and the mean difference between three measures of the AC/A ratio are given in Table IV. The correlations between haploscope response and haploscope stimulus AC/A ratios are all statistically significant, but only one of the correlations between the haploscope and refractor AC/A ratios is significant. For all four subjects the haploscope response AC/A ratio was greater than the haploscope stimulus AC/A ratio (mean difference approximately 1 Δ) and greater than the refractor AC/A ratio (mean difference approximately 0.3 Δ): the refractor AC/A ratio was greater than the haploscope stimulus ratio (mean difference approximately 0.7 Δ).

DISCUSSION

In the present study the stability of the AC/A ratio has been used as a measure of the stability of the relationship between accommodation

TABLE III

Rank Correlation Between AC/A Ratio and Trial

Method	Subjects M.A. n = 10	J.O. n = 10	S.K. n = 9	M.K. n = 9
Halploscope, response	— .06	— .03	— .03	— .33
Haploscope, stimulus	+ .35	— .25	+ .28	— .31
Risley Prism, stimulus, 4 levels	— .43	— .88**	— .14	+ .43
Risley Prism, stimulus, 2 levels	+ .17	— .59*	— .11	— .41

Asterisk indicates rank correlation significant at 5% level; double asterisk indicates significance at 1% level.

TABLE IV

Rank correlation (r_s) and mean difference (d) between haploscope response AC/A, haploscope stimulus AC/A, and clinical AC/A ratios

Subject		$H_R - H_S$	$H_R - C$	$H_S - C$
M.A.	r	+0.67*	—0.08	—0.41
	d	+0.92**	+0.43	—0.49
J.O.	r	+0.85**	+0.21	+0.56*
	d	+0.47	+0.19	—0.28
S.K.	r	+0.83**	+0.18	+0.42
	d	+1.06**	+0.52	—0.54
M.K.	r	+0.87**	+0.53	+0.47
	d	+1.32**	+0.16	—1.16*

Asterisk indicates significance at 5% level, double asterisk 1% level.

and accommodative convergence. The use of a straight line is based on previous results[11] indicating (for these same four subjects and eight others) that although departures from linearity were common, they were small and showed no trend with time. Thus, with the range of accommodation studied (0 to 3.5 D.) and over the time interval involved (about nine weeks) the assumption of linearity has a negligible effect on stability.

How stable is the AC/A ratio? During the nine-week interval the standard deviations of the AC/A ratios did not exceed 0.25 Δ and often they were of the order of 0.1 Δ. The coefficient of variability (100 x standard deviation / mean) was always larger for the refractor AC/A ratio than for the haploscope response AC/A ratio, the range of values being 1.5 to 7.5 per cent. What are the factors responsible for this variability in measurement of the AC/A ratio?

Random error of measurement certainly accounts for some of the variability in the measure of the AC/A ratio. In a previous paper[11] it was pointed out that of 426 r^2 values (twelve subjects, three experimental conditions, about twelve trials each) computed for the fitted straight line, nine-tenths of them exceed 0.90. In these instances about 10 per cent of the variability remains unexplained and is presumably

due to random error of measurement or uncorrelated biological variation.

A practice effect was observed for at least one subject (J.O.) indicating a decrease in the refractor AC/A ratio with time. Other things being equal, a consistent change in the AC/A ratio with time should lead to a larger standard deviation. Indeed, the largest standard deviation occurred for the subject with the significant practice effect. Of the twelve rank correlations between AC/A ratio and trial (four subjects, three experimental conditions), nine were negative suggesting a decrease in AC/A ratio with time. Although this proportion of negative correlations is not statistically significant ($p = 0.07$), there is a suggestion here that weekly retesting of the AC/A ratio was associated with a tendency toward a small decrease in the AC/A ratio. This small negative trend (practice effect) must represent either a form of learning or some seasonal or other relatively short-term environmental effect, otherwise the AC/A ratio would decrease with retesting over the years to some impossibly small value. On the contrary, Fry[9] has found his own haploscope response AC/A ratio to increase with age.

Does the observed variability in the AC/A ratio indicate variability in the neuromuscular system underlying the AC/A ratio? Since the present experiment utilized psychophysical measurements, it is not possible to specify whether the variability was in observational characteristics of the subjects or in the neuromuscular system upon which the AC/A ratio is based. In the subject who showed a significant practice effect, the consistent decrease in the refractor AC/A ratio with time might be associated with systematic error, a regular change in some related function (e.g., a decrease in psychic convergence), or a change in the underlying neuromuscular system. The fact that the observed variations might not have taken place in the neuromuscular system underlying the AC/A ratio does not make the variations any the less "real." When the AC/A ratio is ultimately measured by careful objective means, there should be variability in an amount that is somewhat less than observed in the present study.

Finally, it is against this picture of relative but far from absolute stability that the effects of orthoptics must be evaluated. A subsequent paper[10] deals with this problem.

The author gratefully acknowledges the statistical advice and assistance of Professors Lincoln Moses, Stanford University Statistics Department, and Frank W. Weymouth, University of California School of Optometry.

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ANNOUNCEMENT

ENCYCLOPEDIA OF CONTACT LENS PRACTICE

Dr. Bernard E. Vodnoy, Business Manager of the Encylopedia of Contact Lens Practice, announces that Volume I of the ECLP has been sold out for the second time, is again being reprinted, and will be available by September 15th. Volume I consists of the Syllabus-Manual and Six Supplements totaling 587 printed pages, 268 figures and drawings, and 32 charts and tables.

The Seventh Supplement, which begins Volume II, will be mailed on November 15, 1960. In addition to the sections used in the Initial Six Supplements, Volume II will also include five new sections. The ECLP which is an aid to optometrists fitting contact lenses may be obtained by writing to the Encyclopedia of Contact Lens Practice, 801 North Michigan Street, South Bend 1, Indiana.

THE CLINICAL ACA RATIOS*

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INTRODUCTION

In the graphical method of visual analysis certain optometric test data are plotted to delineate a zone of single, clear binocular vision. The zone is bounded by a base-in line on one side and a base-out line on the other. The base-in line is the limit of negative fusional convergence; the base-out line, of positive fusional convergence. Between these limits of fusional convergence, there is another line which is determined by the induced phoria at far and its counterpart performed at nearpoint. The relative positions of these three lines are illustrated in Figure 1. Fry[1] in discussing this zone states, "The lines representing the limits of positive and negative fusional convergence are usually straight and parallel to each other. If this condition is not approximated the aberrant findings should be rechecked. Since these lines are also approximately parallel to the lines connecting the phorias with various stimuli to accommodation, the slope of these lines can be used as a check on the ACA ratio. . . . In general the shape of this area approximates a parallelogram. The line representing phoria findings runs approximately parallel to the two sides. . . . The ACA ratio which is given by the slope of the phoria line and also by the slope of the lines which represent the limits of positive and negative fusional convergence."

If we arbitrarily assume that the ACA ratio is a constant, it must follow that all three lines in Figure 1 must be parallel to each other. Since the ACA ratio is the slope of these lines, we have that $\theta_1 = \theta_2 = \theta_3$. From this concept, we can, by using any two test values on a particular line, derive a formula for the slope of the line and thereby obtain the ACA ratio.

The base-in line is clinically determined by the negative fusional reserve at far (#11); negative relative convergence at near (#17A) and positive relative accommodation at near (#20).

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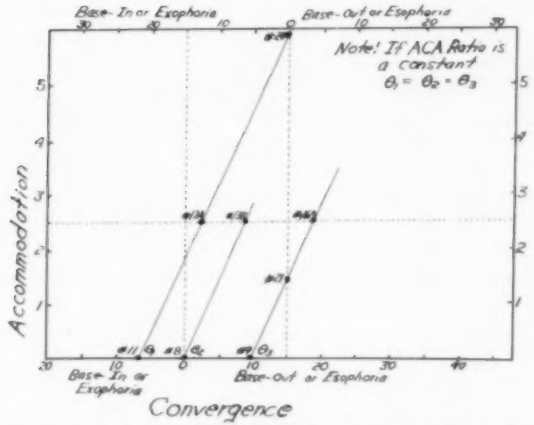

Fig. 1. The theoretical zone of single and clear binocular vision. (After Fry.)

The base-out line is clinically determined by the positive relative convergence at far (#9); negative relative accommodation at near (#21) and positive relative convergence at near (#16A).

The phoria line is clinically determined from the induced phoria at far (#8) and the induced phoria at near (#13B).

For simplicity, the various test numbers will be used instead of their names. The following sign nomenclature will be followed: Positive values are the base-out, esophoria and plus tests; negative values are the base-in, exophoria and minus tests.

Calculation of the ACA Ratio Based Upon θ_1 (Base-In Line)

A. If we consider #11 and #17A (see Figure 1), we have:

Change in convergence = 15 — #11 + #17A

Change in accommodation = 2.50

$$\text{Therefore, ACA ratio} = \frac{15 - \#11 + \#17A}{2.50} \qquad (1)$$

B. If we consider #17A and #20 (see Figure 1), we have:

Change in convergence = — #17A

Change in accommodation = — #20

$$\text{Therefore, ACA ratio} = \frac{\#17A}{\#20} \qquad (2)$$

C. If we consider #11 and #20 (see Figure 1), we have:

Change in convergence = 15 — #11

Change in accommodation = 2.50 — #20

$$\text{Therefore ACA ratio} = \frac{15 - \#11}{2.50 - \#20} \quad \ldots\ldots (3)$$

Calculation of the ACA Ratio Based Upon θ_2 (Phoria Line)

D. If we consider #8 and #13B (see Figure 1), we have:
Change in convergence = 15 — #8 + #13B
Change in accommodation = 2.50

$$\text{Therefore, ACA ratio} = \frac{15 - \#8 + \#13B}{2.50} \quad (4)$$

Calculation of the ACA Ratio Based Upon θ_3 (Base-Out Line)

E. If we consider #9 and #21 (see Figure 1), we have:
Change in convergence = 15 — #9
Change in accommodation = 2.50 — #21

$$\text{Therefore, ACA ratio} = \frac{15 - \#9}{2.50 - \#21} \quad \ldots\ldots (5)$$

F. If we consider #21 and #16A (see Figure 1), we have:
Change in convergence = #16A
Change in accommodation = #21

$$\text{Therefore, ACA ratio} = \frac{\#16A}{\#21} \quad \ldots\ldots (6)$$

G. If we consider #9 and #16A (see Figure 1), we have:
Change in convergence = 15 — #9 + #16A
Change in accommodation = 2.50

$$\text{Therefore, ACA ratio} = \frac{15 - \#9 + \#16A}{2.50} \quad (7)$$

Seven equations for calculating the slope of the three lines comprising the limits of the zone of clear and single vision have been derived. Since the slope of these lines is the rate of change of convergence per unit of accommodation, they are the measure of the accommodative-convergence accommodative ratio (ACA ratio).

CLINICAL DATA

Nine senior optometric students agreed to have a weekly visual examination for a period of ten weeks. Of this group, only two finished the complete series of examinations. The remainder of the group finished four or more weekly examinations. Standard clinical testing procedures were followed. The equipment and physical set-up of the examining room remained constant throughout the testing period. The same examiner-patient relationship was present at all times. Substituting these clinical data into the appropriate formulas for the ACA Ratio, we obtained the data presented in Table 1.

TABLE 1

The ACA Ratio as Determined by the Various Formulas

	Formula Number						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
E.P.D.	4.4	4.0	4.2	4.8	12.0	7.1	7.6
	1.6	4.9	3.5	4.6	—40.0	3.6	8.0
	3.2	3.4	3.3	4.8	.....	.....	4.4
	1.6	4.5	3.3	4.4	—36.0	.....	9.2
	4.0	3.5	3.7	5.2	6.7	.....	7.6
	4.4	2.5	3.1	5.2	— 5.7	4.9	8.0
	2.8	4.9	4.0	4.8	.....	4.8	6.8
	4.8	4.7	4.3	5.4	20.0	8.1	8.8
	6.4	2.7	4.2	5.2	.....	5.6	6.8
	3.6	4.0	3.8	4.4	— 6.7	5.9	7.2
C.R.W.	3.6	4.0	3.8	4.4	.....	5.6	10.0
	6.8	3.7	5.0	4.4	— 9.0	9.3	12.4
	5.2	3.2	4.0	5.2	18.0	.....	10.0
	5.2	4.3	4.7	4.8	6.7	.....	13.2
	4.4	5.3	5.0	4.4	.....	9.6	— 8.4
	6.0	3.8	4.7	5.6	.....	6.4	7.6
	7.6	3.3	5.3	5.6	—52.0	8.7	4.4
J.W.W.	6.0	3.1	4.1	3.2	.....	0.8	5.2
	0.8	7.4	4.5	3.6	40.0	1.3	5.2
	9.2	2.3	5.2	2.8	44.0	1.8	6.0
	2.4	6.2	4.7	2.8	44.0	3.6	7.6
	3.2	4.2	3.9	2.0	—52.0	1.5	6.8
	2.4	4.5	3.7	3.2	—44.0	0.4	4.8
	—0.3	5.6	3.6	2.0	—22.0	1.3	6.0
	3.2	4.9	4.2	2.0	—22.0	2.7	7.6
	2.8	6.0	4.8	2.8	—44.0	2.9	7.6
	0.4	6.4	4.0	0.4	— 9.6	2.1	8.0
H.H.	0.0	5.6	3.6	4.4	—12.0	5.2	8.8
	0.8	5.2	3.7	5.2	— 2.0	6.9	10.4
	2.0	6.8	4.7	3.6	— 2.0	11.0	14.0
	1.2	4.8	3.6	5.2	—16.0	7.3	12.0
	0.4	5.5	3.7	4.4	4.0	4.3	4.4
	0.0	5.6	3.6	4.4	— 6.8	5.2	8.8
M.J.E.	2.8	4.4	3.6	2.8	.....	13.6	16.8
	—0.4	10.4	5.0	5.2	24.0	7.1	8.8
	3.2	6.5	5.0	6.0	— 2.7	8.0	11.2
	0.8	5.9	3.7	4.0	—24.0	9.1	12.4
E.J.H.	6.8	4.0	5.3	7.6	.....	8.0	10.8
	4.4	4.4	4.4	6.4	28.0	9.3	11.2
	6.0	18.0	4.0	6.8	24.0	8.0	8.8
	7.2	1.9	4.1	6.8	.....	3.6	6.4
E.B.	3.2	3.0	3.1	7.6	—36.0	16.0	10.0
	5.6	3.3	4.4	8.4	— 4.0	5.3	5.2
	4.8	5.0	4.9	7.6	— 2.0	12.0	8.8
	2.8	4.3	3.6	8.4	.....	10.4	7.2
	4.8	3.0	3.8	8.0	.....	6.4	7.2
	5.2	3.3	4.6	8.8	9.4	14.3	10.4
	—0.8	17.6	5.3	7.6	—24.0	3.3	5.6
	3.6	3.3	3.4	7.2	—20.0	9.5	12.4
S.C.	1.2	3.7	3.0	4.0	.....	5.6	6.0
	4.4	3.5	3.8	4.8	28.0	8.4	10.4
	5.2	3.0	3.7	3.2	12.0	7.0	7.6

(Table 1 continued on page 528)

(Table 1 continued from page 527)

	5.2	3.1	3.8	8.0	20.0	7.3	6.0
	2.4	3.3	3.1	5.6	10.0	6.0	6.8
	9.2	3.2	4.9	5.6	.....	6.4	5.2
	5.2	2.9	3.7	5.6	.....	4.8	2.8
	3.6	3.6	3.7	4.0	6.0	8.5	8.0
I.A.H.	6.0	2.4	3.8	2.0	—14.0	3.3	13.6
	6.8	1.6	3.7	3.6	—18.0	2.7	12.5
	6.8	2.7	4.5	2.4	— 1.3	2.8	15.2
	4.8	3.7	4.2	2.4	32.0	4.0	12.4
	5.2	2.5	3.5	3.2	.....	5.6	13.2
	4.8	4.0	4.4	1.2	.....	4.0	13.6

RESULTS

An examination of the tabulated data of Table 1 reveals that of the seven clinical formulas used to calculate the ACA ratio, two of the formulas gave the most consistent or least variable values. These are:

$$\text{ACA ratio} = \frac{15 - \#11}{2.50 - \#20} \qquad (3)$$

$$\text{ACA ratio} = \frac{15 - \#8 + \#13B}{2.50} \qquad (4)$$

Equation (4) is the familiar graphical (Fry) method for computing the ACA ratio, while equation (3) is the slope of the base-in line.

In order to compare the variability in the ACA ratio values obtained with each of the above formulas, the data for each observer was converted into a coefficient of variation[2] (V). The coefficient of variation (V) is a measure of variability which takes into consideration both the arithmetic mean (M) and the standard deviation. The data for each subject is tabulated in Table 2. The average coefficient of variation (V) obtained by the use of formula (3) for all of the subjects is 12.6; while the average coefficient of variation (V) obtained by the use of formula (4) is 19.4. Thus, by the use of formula (3) which is based upon the base-in line and selecting as our reference points on this line negative fusional reserve at far (#11) and positive relative accommodation at near (#20), we obtain a value for the ACA ratio which has 35 per cent less variation than by the standard phoria equation (4). The improvement in the lowered coefficient of variation of the computed ACA ratio by the base-in equation (3) is also evident by making a direct comparison of the average standard deviation for this equation as against the standard deviation found by using the phoria equation. The increased stability of the computed ACA ratio value as found by means of the base-in equation may be due to one or more of the following factors:

A. The slope of the base-in line is determined over a much

TABLE 2

The Variability (V) of the ACA Ratio as Computed by Formulas Three and Four

	Formula Three			Formula Four		
Observer	Mean	Std. Dev.	V	Mean	Std. Dev.	V
E.P.D.	3.7	0.41	11.1	4.9	0.33	6.7
C.R.W.	4.6	0.51	11.1	4.9	0.51	10.4
J.W.W.	4.3	0.49	11.4	2.5	0.87	34.8
H.H.	3.8	0.40	10.5	4.5	0.64	14.2
M.J.E.	4.3	0.68	15.8	4.5	1.21	26.9
E.J.H.	4.5	0.52	11.5	6.9	0.44	6.4
E.B.	4.1	0.73	17.8	8.0	0.51	6.4
S.C.	3.7	0.54	14.6	5.1	1.90	37.2
I.A.H.	4.0	0.38	9.5	2.5	0.78	31.2
	Average Mean = 4.1			Average Mean = 4.9		
	Average Std. Dev. = 0.52			Average Std. Dev. = 0.80		
	Average V = 12.6			Average V = 19.4		

greater accommodative change than the slope of the phoria line. This increased separation of key points on the graph (see Figure 1) may tend to minimize experimental errors.

B. The position of the base-in line may be less influenced by psychic factors than the phoria line.

C. The clinical ease of obtaining a patient response under proper accommodative control seems better for a duction test and a blur test than it would be for a phoria measurement. This is particularly true for the nearpoint phoria test.

The ACA ratio as computed by means of the base-in equation has high reliability, but yet more important is the question, "Does it have adequate validity?" Since the phoria equation (4) is used as a standard method for the computation of the ACA ratio it was selected as the

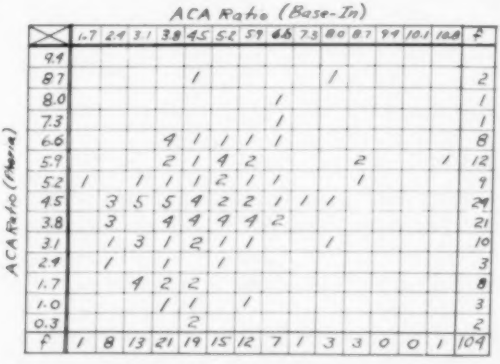

Fig. 2. The scattergram of the relationship between the ACA ratio determined by means of the phoria formula (#4) and the base-in formula (#3).

criterion. The linear coefficient of correlation (r) between the ACA ratio determined from the two equations (#3 and #4) for 104 non-presbyopic, binocular patients was performed (see Figure 2). The linear coefficient of correlation between the ACA ratios as determined from the base-in formula (3) and the phoria formula (4) for the clinical sample used was +0.31. This coefficient of correlation is significant at the one per cent level. Unfortunately, its low magnitude makes it impossible to predict the base-in ACA ratio if the phoria ACA ratio is known or vice versa.

The lowness of the correlation coefficient found between the ACA ratio as computed from the two formulas may be due to certain factors such as psychic convergence or depth of focus; or it might mean that the zone of single and clear vision as depicted in Figure 1 does not exist clinically. If we take the mean values for clinical data as given by Morgan,[3] and plot these data to illustrate the clinical shape of the zone of clear and single vision (see Figure 3), it is noted that none of the lines are parallel to each other. If, however, we construct a new line based upon the negative fusional reserve at far (#11) and positive relative accommodation at near (#20), we note (see Figure 3) that this constructed line is more nearly parallel to the phoria line than either the base-out or base-in lines.

The fluctuation in ACA ratio when based upon careful clinical technique is perhaps best illustrated when we use the clinical data given by Morgan.[3] If we substitute these clinical mean values in the formulas which have been derived for the computation of the ACA ratio, we have:

ACA ratio = 3.4 ..... (1)
ACA ratio = 5.5 ..... (2)
ACA ratio = 4.5 ..... (3)
ACA ratio = 5.2 ..... (4)
ACA ratio = 12.0 ..... (5)
ACA ratio = 8.5 ..... (6)
ACA ratio = 9.2 ..... (7)

It will be noted that three of the formulas give values for the ACA ratio which are closely clustered. These are the phoria ACA ratio (4), base-in ACA ratio (3) and PRA ACA ratio (2). The remaining formulas produce values for the ACA ratio which indicate considerable variation in the slope of their lines.

The base-in ACA ratio (3) will be of value in checking the ACA ratio as obtained from the phoria line (4). It has been found that the base-in formula (3) is useful in obtaining the ACA ratio of young

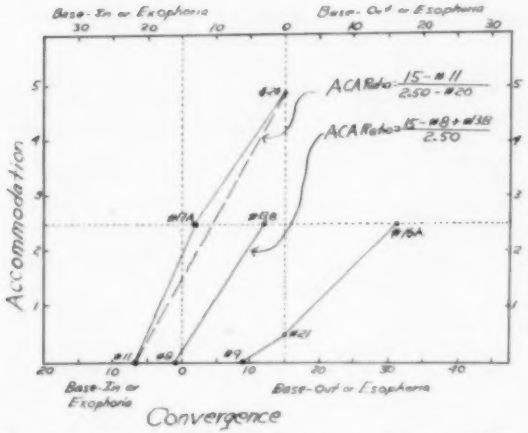

Fig. 3. The clinical zone of single and clear binocular vision. (After Morgan.)

children. The child responded more readily to instructions of, "tell me when the letters are blurred or double" than to the vertical alignment response necessary in performing the phoria tests.

SUMMARY

A series of seven formulas have been derived for the determination of the ACA ratio from the key clinical data ordinarily plotted to delineate the zone of single and clear binocular vision. The great differences and variability found for the ACA ratio as computed from these seven formulas would indicate that the usual way of drawing this zone as a series of parallel lines does not hold for clinical data.

In calculating the ACA ratio from clinical data, minimum variability was found when using the base-in formula:

$$\text{ACA ratio} = \frac{15 - \#11}{2.50 - \#20} \qquad (3)$$

Where #11 is the negative fusional reserve at far, and #20 is the positive relative accommodation at near the correlation coefficient obtained for the presence of a linear relationship between the base-in and the phoria formulas for the ACA ratio is highly significant. Although the magnitude of the coefficient of correlation obtained is too low for individual comparisons.

The calculation of the ACA ratio by means of the base-in formula will provide a check upon the test magnitude obtained by means of the phoria formula. The base-in formula for the ACA ratio will be of

value in determining this ratio for young children where it might be difficult to obtain a phoria response.

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HENRY W. HOFSTETTER

A SURVEY OF CURRENT FITTING TECHNIQUES FOR CORNEAL CONTACT LENSES*

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Los Angeles, California

In the present day field of contact lenses, changes are being introduced at such a fast pace, it is a difficult task to keep abreast of advancements, new ideas and theories. To complicate this problem, many approaches to the fitting of corneal contact lenses do not agree with each other, and often as not, are in direct contradiction.

This places the individual practitioner in the difficult position of devoting considerable time to this single phase of his practice to keep fully informed of current developments. Not only does the practitioner struggle to keep his desk clear of educational material on contact lenses, he likely terminates his studies in a state of confusion from reading conflicting ideas and recommendations.

A survey for the purpose of evaluating the mass of material written on this subject, may yield some data which would facilitate the utilization of this information.

With this in mind, the author carefully examined the published material of selected men and contact lens laboratories, and mailed questionnaires to some of these sources, to obtain specific information for comparative purposes.

The men and laboratories included in this survey are as follows: Mr. Gene Copolillo, Mueller Welt Contact Lenses, Inc.; Conforma Contact Lens, Inc.; Dr. Benjamin Bisgeier, Contact Lens Foundation; Dr. Norman Bier; P. M. Laboratories; Dr. H rold Gates, Kontur Kontact Lens Co., Inc.; Precision-Cosmet Company, Inc.; Obrig Laboratories, Inc.; The Plastic Contact Lens Company; Dr. Gilberto Cepero; Dr. George Butterfield, George H. Butterfield and Son; Dr. Louis Zabner, Solex Laboratories, Inc.; Dr. Murray Davidson, Murray Contact Lens Corp.; Dr. Allen A. Isen, Frontier Contact Lens Co.; Mr. Noel Stimson, Stimson Lens Laboratories; Dr. Martin Weinberger, United Contact Lens Corp.; Midwest Scientific Company; and Dr.

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†Optometrist, Member of Faculty, Fellow, American Academy of Optometry.

Solon Braff, Calcon Laboratories. This represents a total of eighteen sources.

The questionnaire contained the following questions:

1. Recommendations for the relationship of the base curve of the corneal contact lens to the central curves of a relatively spherical cornea.
2. Recommendations for the relationship of the base curve of the corneal contact lens to the central corneal curves in cases of significant astigmatism.
3. Recommendations as to methods for determining the starting diameter.
4. The average diameter currently used.
5. Recommendations as to methods for determining the diameter of the posterior optical zone.
6. The average diameter of the posterior optical zone currently used.
7. Recommendations as to methods for determining the radius of the secondary curve.
8. Recommendations as to methods for determining the width of the secondary curve.
9. Recommendations as to methods for determining the radius of the tertiary curve.
10. Recommendations as to methods for determining the width of the tertiary curve.
11. Description of the optimum riding position.
12. Description of the optimum fluorescein pattern.
13. Opinions as to the importance of performing office adjustments.
14. Opinions as to the need of a trial case.
15. Description of the recommended construction of the posterior surface (single curve, bicurve, tricurve, etc.).
16. Method used in manufacturing (lathe, molded).

A compilation of answers obtained from the questionnaire and from the writings of the men and laboratories involved in this survey are listed below.

Since one source often gave more than one recommendation, or more than one approach, or gave no recommendations, the total number of recommendations or answers to each of the questions may total more or less than 18, the total number surveyed.

Question No. 1—Recommendations for the relationship of the base curve of the corneal contact lens to the central curves of a relatively spherical cornea.

13—Fit parallel to the flattest central curve.
6—Fit parallel to the intermediate zone of the cornea.
2—Fit parallel to the peripheral zone of the cornea.
3—Fit slightly steeper than the flattest central curve.

As can be seen, the majority follow a fitting technique which has been popular for the last several years, that of selecting a base curve for the corneal contact lens which is parallel to the flattest central corneal reading. The fact that the majority utilizes this approach, however, does not necessarily mean that this is the best or most recent approach. As a matter of fact, the majority usually does not follow the most recent approaches, since there is a lag in time between the advancement of new techniques and the adoption of these techniques. This appears to be the case in this instance. Six of those questioned advanced a method not presented in a similar survey conducted one year ago, the technique of fitting lenses parallel to the more flatly curved intermediate zone of the cornea (the intermediate zone of the cornea refers to the region of the cornea between the optical cap and the extreme periphery). In effect, this means fitting corneal lenses slightly flatter than the flattest central curve, the purpose being to avoid intermediate touch and thus eliminate interference in lacrimal flow and prevent metabolic disturbances.

This latter technique gives greater consideration to the relationship of the size of the optical zone of the cornea to the optical section of the corneal lens. In cases where the optical zone of the cornea is smaller than the optical section of the lens, a base curve flatter than the flattest central curve is used. The amount of flattening required is related to the difference between the sizes of these two dimensions, and to the rate of change in corneal curves between the central and peripheral cornea. This latter factor may be approximated by measuring the more peripheral corneal areas with the keratometer or ophthalmometer. According to this approach, the fitting of lenses parallel to the flattest central curve of the cornea is reserved for cases in which the optical cap of the cornea is relatively large, and in which the optical section of the corneal lens is either equal to, or smaller than, the optical cap of the cornea.

It has been stated by Isen and Moss that a decrease of 0.25 diopters (an increase of 0.05 mm.) in the base curve will, on the average, move the intermediate touch area out a total of 0.5 mm. If this be used as a guide to determine the degree of flattening necessary, an optical zone of a corneal lens 1 mm. larger than the optical cap of the cornea, would require a base curve 0.10 mm. flatter than the flattest central curve. Estimates as to the average size of the corneal cap differ considerably.

varying anywhere from 4 to 8 mm. If an average of 6 mm. is arbitrarily taken, and this is compared to the optical zone of the lens used, one may approximate the amount of flattening necessary in the lens (as per the above example). Of course, lenses placed on the eye should be used to verify this aspect of the fit.

Thus, instead of the much referred to "on K" approach, which refers to fitting parallel to the flattest central curve, the future indicates that corneal lenses will be fitted "on K," but now parallel to the intermediate zone of the cornea.

The method of fitting considerably flatter than the flattest central curve, to the point of obtaining pronounced central touch (this may be termed fitting "on K" for the peripheral cornea) has all but been abandoned and is rapidly heading for extinction. Of the few that have, in the past, advocated this approach, all have, in some way, demonstrated less enthusiasm for it. Instead, they appear now to be accepting the technique of minimizing central touch.

The same is true for those advocating the fitting of lenses steeper than the flattest central curve. This approach never did have a large number of advocates, and of the few that formerly did, a number have changed within the last year to the approach of fitting "on K" to central cornea.

In summary, then, though the majority in this survey fit parallel to the flattest central corneal curve, the technique of fitting slightly flatter than the flattest central curve appears to be gaining popularity when compared to the results of a survey conducted last year. The techniques of fitting lenses considerably flatter than the flattest central curve or steeper than the flattest central curve, have experienced a decline in popularity the past year, with only a small minority still clinging to these methods.

Question No. 2—Recommendations for the relationship of the base curve of the corneal contact lens to the central corneal curve in cases of significant astigmatism.

1—Fit a lens to conform in the same relationship to all meridians by using a corneal lens having a toric posterior surface.

4—Fit parallel to the flattest central curve.

4—Fit midway between the principal meridians (starting this approach when astigmatism is 1.00 D. to 2.00 D. or more).

4—Fit slightly steeper than the flattest central curve, but not so steep as to be midway between the two principal meridians.

2—Fit slightly flatter than the flattest central curve.

1—Fit slightly steeper in with-the-rule astigmatism and slightly flatter in against-the-rule astigmatism.

5—Indicate fitting technique is the same as that for a relatively spherical cornea.

The degree of astigmatism warranting a change in the fitting approach ranged from 1.00 D. to 6.00 D., over 2.00 D. being the median.

There is much less agreement in fitting the higher astigmatic corneas than in fitting the relatively spherical type. Also, there is no great agreement as to what degree of astigmatism necessitates a different fitting approach. Of those recommending fitting steeper than the flattest central curve of the cornea, the average amount of astigmatism considered necessary for altering the fitting technique was 2.00 D.

It is interesting to note that only one source attempts to fit highly astigmatic cases with posterior toric surfaces. Fitting such a lens would more nearly conform to all the corneal curves, in contrast to fitting such corneas with spherical lenses which require the toric cornea to adapt and conform to a spherical surface.

It is believed that with the newer manufacturing techniques of providing both toric anterior and posterior surfaces, the fitting of bitoric corneal lenses for cases of high astigmatism will gain steadily in popularity.

In summary, no one trend is obvious in the fitting of highly astigmatic corneas. It has been noted, however, that a few of the sources, which last year recommended fitting steeper than the flattest central curve no longer feel so strongly toward this fitting approach. This has been indicated by less emphasis on this technique, as well as actual changes in the recommendations by some to now fit parallel to the flattest central curve or to go only slightly steeper than the flattest central curve. Some now reserve fitting steeper than the flattest central curve for those cases which do not respond to fitting the cornea as though it were spherical.

Question No. 3—Recommendations as to methods for determining the starting diameter.

11—Relate the starting diameter to the horizontal dimension of the cornea (visible iris). Four of these eleven deduct an arbitrary amount from this corneal dimension, the average being 1.7 mm.

4—Relate the starting diameter to the corneal curves (smaller lenses on steeper corneas, larger lenses on flatter corneas).

7—Relate the starting diameter to the vertical dimension of the palpebral fissure.

4—Recommend trial lenses for this determination.
3—Relate the starting diameter to pupillary size.
2—Relate the starting diameter to the degree of eyelid tenseness.
3—Relate the diameter to the amount of lag with eye movement, or the degree of stability of the riding position.
2—Relate the diameter to the lower eyelid margin (should be free of).
1—Relate the diameter to movement of the lens with blink.
2—Relate the diameter to the centering characteristics of the lens on the cornea.
1—Relate the diameter to the superior limbus (should not ride above it).
1—Relate the diameter to the power of the lens prescription.
1—Relate the diameter to the amount of astigmatism.
1—Relate the diameter to the degree of proptosis of the eyeball.
1—Relate the diameter to the type of use of the lenses (as for sports).
1—Relate the diameter to the angling of the eyelid margin at the canthi.
1—Relate the diameter to the sagitta of the cornea.

The horizontal dimension of the cornea appears to be the most common factor used for determining the starting diameter of the corneal lens. The size of the vertical dimension of the palpebral fissure ranks second. Undoubtedly, these are two of the most important anatomical features effecting consideration as to corneal lens size. One should not be misled, however, into thinking that the other factors listed are of minor importance. The recommendations made, as has been mentioned, are for starting diameter only. The observation of lenses on the eye will be the ultimate criterion as to the size indicated. The inter-relationships of all of the factors mentioned in this survey (17 in all) may then be observed and interpreted so that the proper size for that eye may be precisely determined.

Question No. 4—The average diameter currently used.

The range was from 9.2 mm. to 11.8 mm.

The mean was 9.87 mm. and the median 9.80 mm., the latter two figures being derived from 18 sources.

For bicurve lenses, the mean was 9.80 mm. and the median 9.75 mm., the latter two figures being derived from 11 sources.

For tricurves, both the mean and the median was 9.85 mm., this figure being derived from 7 sources.

The above indicates that the trend is now back to slightly larger lenses than the 9.0 or 9.2 so persistently recommended by some a few years ago. No doubt, the factors of better stabilization, better centering, better vision, and greater comfort have led to this change.

Only one source covered in this report states that the average diameter used is 9.2, and in this instance, it only applied to their bicurve lenses. The same source states that the average for their tricurve lens, which they are now more inclined to recommend, is 9.85 mm.

It should be mentioned that some gave figures for both bicurve and tricurve lenses, and in such cases, the figures given for the bicurve lens was almost always smaller than those for the tricurve lens. The majority indicated they utilize both bicurve and tricurve lenses.

Question No. 5—Recommendations as to methods for determining the diameter of the posterior optical zone.

9—Hold the size of the posterior optical zone to a fairly constant dimension.

3—Vary the size of the optical zone with the posterior curve construction (smaller in tricurve lenses and larger in bicurve lenses).

3—Vary the size of the posterior optical zone with the size of the pupil.

5—Vary the size of the posterior optical zone with the diameter of the corneal lens (larger zone in larger lenses).

3—Vary with the base curve of the lens (smaller in steeper lenses).

2—Determine this dimension by the fluorescein pattern of trial lenses.

1—Varies with the fitting approach (smaller diameter if fitting steeper than the flattest central corneal curve, and larger diameter if fitting parallel to the flattest central corneal curve).

The majority favor holding the size of the optical zone fairly constant. This would mean that a change in the diameter of the lens is reflected by a change in the width of the peripheral curves. A significant number, however, vary the size of the optical zone of the lens with diameter or base curve. This latter group is apparently basing their recommendations on information that the larger the corneal size, the larger the size of the optical cap of the cornea. Therefore, larger corneas (and usually flatter corneas) are fitted with larger optical zones.

An obvious limiting factor in the size of the posterior optical

zone is pupillary size in dim room illumination.* As is known, the optical zone, for best vision, should clear the pupillary margin during blink and eye movement, and should be large enough to accommodate increase in pupillary size in dim room illumination.

One recommendation utilizes pupil size as the only criterion. However, it may be more practical to utilize pupillary size to determine the minimum diameter of the optical zone.

The fitting of bicurve and tricurve lenses also appears to be influencing the size of the optical zone of the lens. Those giving recommendations for both bi- and tricurve lenses tend to recommend smaller zones in the tricurve and larger zones in the bicurve. This survey shows that optical zones in tricurve lenses average 0.5 mm. smaller than in bicurve lenses.

Some who fit steeper than the flattest central corneal curve attempt to overcome the blockage of the free flow of lacrimal fluid, which such fits often create, by resorting to slightly smaller optical zone sizes.

There is some direct conflict in approaches here. For example, one approach provides for larger optical zone sizes on large corneas, while another approach provides for smaller optical zones on the large diameter tricurve lenses.

The clearing of the pupillary margin and the free flow of lacrimal fluid, in the final analysis, appear to be the two principal underlying factors in determining this dimensic ..

Question No. 6—The average diameter of the posterior optical zone currently used.

The range was from 6.0 mm. to 8.2 mm.

The mean was 7.71 and the median was 7.50 mm.

The mean in bicurve lenses was 7.3 mm. (3 sources).

The mean in tricurve lenses was 6.8 mm. (3 sources).

The average of 7.71 mm. and the median of 7.50 mm. indicates that pupil size and lens movement and centering acts to limit the possible variations in the size of the optical zone of the lens. The average pupil size, in dim room illumination, may be considered to be approximately 4 to 5 mm. Allowing clearance for eccentric positioning of the lens,

*A method the author uses to determine the maximum size of the pupil in dim room illumination, is to direct a black light source onto the eyes in a darkened room. The crystalline lens will fluoresce under these conditions, clearly defining the pupillary limits, and if a P.D. rule, or some other scale is now placed against the pupil, while the patient fixates a target at infinity, one may fairly accurately measure the maximum pupillary size. This measurement is usually performed with a magnifying lens (as in the Burton black light) to facilitate the reading; the black light will provide sufficient illumination to read the calibrations on the measuring device.

for lag of lens with eye movement, and for lens movement with blink, would tend to make the optical zones fairly large. These factors appear to carry more weight that the size of the optic cap of the cornea. Since allowances for the above factors usually results in an optical zone size which exceeds that of the corneal cap, it can be seen, again, the reasons for the trend of fitting corneal lenses "on K" for the intermediate zone of the cornea.

Question No. 7—Recommendations as to methods for determining the radius of the secondary curve.

11—Based upon a fixed relationship to the base curve: from 0.5 mm. to 1.50 mm. flatter than the base curve (the median being 1.0 mm. flatter than the base curve).

6—A variable relationship to the base curve of the lens; less difference between the secondary curve and base curve in lenses of shorter radii than in lenses of longer radii. The median difference in steeply curved lenses was 0.4 mm. and the median difference in flat lenses was 1.5 mm.

2—A constant radius is used, not related to the base curve.

2—Relate to the type of power of the lens, steeper secondary curves in plus lenses and flatter secondary curves in minus lenses.

1—Varies with the fitting technique, a greater difference if the fit of the lens is steeper than the flattest central curve, and a smaller difference if the fit of the lens is parallel to the flattest central curve.

Here again the majority, which recommend a fixed relationship to the base curve of the lens, do not reflect the newer trends. Compared to a similar survey conducted one year ago, the newer trend (recommended by six) is to vary the degree of flattening of the secondary curve in relationship to the base curve of the corneal lens. This method employs smaller differences between the secondary curve and base curve in steeply curved corneal lenses, and vice versa for flat corneal lenses. This procedure for determining the radius of a secondary curve may be based on the assumption that steeper corneas flatten less toward the periphery than larger corneas, or that the larger lenses have larger optical zones, and thus the secondary curve area of the contact lens would rest on a more peripheral, and thus flatter portion of the cornea.

Question No. 8—Recommendations as to methods for determining the width of the secondary curve.

7—Vary with the diameter of the lens. Four of the seven hold the optical zone constant; two employ smaller widths in

larger diameter lenses and larger widths in small diameter lenses. The average here was 1.10 mm. wide.

4—Use a constant width. The range was from 0.4 to 1.25 mm. with a median of 0.5 mm. wide. The dimension used varied with whether the lens was one of bicurve or tricurve construction.

2—A proportion of the total width of the peripheral curves (one. $\frac{1}{2}$ of the width of the peripheral curves. and one. $\frac{2}{3}$ of the width of the peripheral curves).

3—Vary with the base curve of the lens (wider in steeper lenses).

3—Vary in relationship to both the diameter and optical zone of the lens (the mean was 1.5 mm. wide).

Three different approaches appear to be most commonly used in determining the width of the secondary curve: (1) Keeping the optical zone of the lens a constant size and varying the secondary curve width with change in diameter: (2) varying the size of the optical zone (larger in larger lenses. and smaller in smaller lenses) and keeping the secondary curve width of a relatively constant size: and (3) varying both the width of the secondary curve and the diameter of the optical zone of the lens as the diameter varies.

The thought behind the first approach probably is that the optical zone must be large enough to cover the pupillary area at all times. and cannot be altered by any great amount. Thus. with variation in the size of the lens. the width of the secondary curve. or the total width of the peripheral curves is varied. The thought behind the second approach may be that larger corneas have larger optic zones. and vice versa. Thus. in the larger lenses. the increase in the size is made up primarily by increasing the size of the optical zone. and not by increasing the width of the secondary curve. The logic behind the third approach may be that even though the larger corneas have larger optical caps. not all of an increase in diameter can be made up by increasing the optical zone. and that some of the change in the diameter of the lens will have to be reflected by a change in width of the secondary curve. Therefore. both the optical zone size and the width of the peripheral curves would be altered as the diameter varies.

Comparison of these recommendations to those of a year ago indicates a trend to use larger optical zone sizes and relatively narrower secondary curve widths in the larger lenses. and vice versa in the smaller lenses.

Question No. 9—Recommendations as to methods for determining the radius of the tertiary curve.

3—A variable relationship to the base curve: lesser difference in steep lenses, greater difference in flat lenses. The range was from 0.8 mm. to 1.8 mm. flatter in steep lenses, the mean being 1.3 mm.; the range was from 1.5 mm. to 3.5 mm. flatter in flat lenses, the mean being 2.5 mm.

1—A constant relationship to the base curve (2.0 mm. flatter).

2—Related to the type and amount of power in the lens; less flattening in higher powers and in plus lenses.

4—An independent constant. Three used a 12.25 mm. radius, and one a 10.50 radius.

7—Recommended bicurve lenses only.

Although a variety of techniques are offered, no one method is favored by a majority. The most recent approaches, however, are to alter the tertiary curve in either a fixed or variable relationship to the base curve.

The tertiary (peripheral) curve is not designed to parallel the peripheral cornea, but is invariably made flatter than the peripheral cornea to keep the periphery of the lens open and provide an entrance for tear fluid. This should be the determining factor in selecting the radius of the tertiary (peripheral) curve. A deep green fluorescein pool will be seen surrounding the periphery of the lens if this radius is sufficiently long. If the radius of the tertiary curve is flatter than necessary to keep the lens open, bubbles will often be seen forming about the edge of the lens, especially when the patient blinks.

Question No. 10—Recommendations as to methods for determining the width of the tertiary curve.

2—A proportion of the total width of the peripheral curves (one ⅓ of the width of the peripheral curves, and one ½ of the width of the peripheral curves).

5—Maintain a constant width in all tricurve lenses (the average being 0.5 mm.).

1—Relate to the type of refractive power in the lens (the average being 0.6 mm.).

1—Relate to the base curve of the lens (narrower in steeper lenses).

3—Varies with the relationship of the size of the posterior optical zone and the diameter of the lens.

More or less general agreement is found in recommendations for determining the width of the tertiary (peripheral) curve of a tricurve lens. In almost all instances a relatively narrow width is recommended, regardless of the method used to determine it, 0.5 to 0.6 mm. being about

average. The purpose of this peripheral curve, as mentioned above, is to keep the lens open peripherally, and only a narrow band is needed to accomplish this. A very wide and flat peripheral curve, which provides an excessive opening for tear fluid, may cause fitting problems, as, for example, increased eyelid sensation, excessive movement of the lens with eye movement and blink, failure to obtain good centering of the lens, and causing air bubble formations both beneath the lens as well as at its edge.

Question No. 11—Description of the optimum riding position.

9—Centered, or nearly so, on the cornea.
4—Within the limbus of the cornea.
3—Free of the lower eyelid margin.
2—A slight lag not to exceed 2.0 mm. with eye movement.
2—Slight movement with blink.
1—Below the upper eyelid margin.
1—A slight and slow drop when the lids are retracted.

There is great agreement in this instance. Almost all sources are of the opinion that the optimum riding position of a corneal lens is one which is and remains stabilized and centered on the cornea, which does not indent the sclera by riding over the limbus, and which remains as free of the eyelid margins as is possible.

Question No. 12—Description of the optimum fluorescein pattern.

12—Faint centrally and deep peripherally.
4—No intermediate touch.
2—Intermediate touch is acceptable.
2—Dark centrally with gradually increasing depth of the fluorescein layer from the center to the periphery of the lens.
1—A central pool of fluorescein, a pronounced intermediate dark ring, and a deep pool peripherally.
1—A deep central pool and dark at the periphery, except at the site of channels.
1—A pool centrally, thin intermediate touch, and a deep pattern peripherally.

The fluorescein patterns which are considered optimum reflect the fitting approach of the source. All of the previously discussed fitting relationships of base curve to cornea are represented by the descriptions of the fluorescein patterns.

There is some conflict in ideas regarding the matter of intermediate touch. Fitting steeper than the flattest central curve of the cornea, or fitting parallel to the flattest central corneal curve with lenses having larger optical zones than the corneal cap, will produce intermediate

touch. If this intermediate touch is characterized by a relatively wide and constant circular band which remains during eye movement and blink, this touch will block or inhibit flow of lacrimal fluid and cause interference in corneal metabolism.

It may be more correct, therefore, to accept intermediate touch only if it is narrow, intermittent, and variable in location. Eye movement and blink should cause the site of the intermediate touch to vary, thus indicating avenues of escape for the lacrimal fluid and no constant pressure on any one area.

Question No. 13—Opinions as to the importance of performing office adjustments.

8—Recommend performing office adjustments.

4—Only when in skilled hands, otherwise the laboratory should perform such adjustments.

1—A laboratory responsibility.

The preponderance of current opinion is that office adjustments should be performed, but only when the practitioner has the equipment and skill to properly accomplish the task. The precise prescribing and filling of prescriptions should keep the necessity of office adjustments to a minimum.

Question No. 14—Opinions as to the need of a trial case.

9—Recommend the use of a trial case.

5—Helpful, but not necessary.

In analyzing the various comments received in answer to this question, the conclusion was made that the availability of a large trial case would materially assist the contact lens fitter in his prescribing, the most frequently cited reason was that it makes it possible to accurately determine the various dimensions of the lens at the initial fitting, and thus considerably reduces the length of time required to fit a patient.

Question No. 15—Description of the recommended construction of the posterior surface (single curve, bicurve, tricurve, etc.).

11—A blended bicurve.

9—A blended tricurve.

2—A single curve lens with a bevel.

No great preference is found for the use of tricurve or bicurve lens construction. Many of the sources indicated that both types were used, as indicated by the needs of the patient, and that no definite stand could be taken in preferring one over the other. The two who utilize single curve lens construction also utilize the approach of fitting flatter than the flattest central corneal curve with pronounced central touch.

Question No. 16—Method used in manufacturing (lathe or molded).

10—Cut by lathe from plastic buttons.

4—Injection mold the posterior surface and cut the anterior surface with a lathe.

1—Injection mold both surfaces.

As the above indicates, the current manufacturing technique employed by the majority is that of the lathe to cut the radius on both surfaces. The technique of injection molding, though discarded by some, has recently been adopted by others.

It appears that the preference for one manufacturing technique over the other is not based on the quality of the end product, but on the financial investment involved and the availability of equipment.

Comments: One of the interesting aspects brought to light by this survey is the number of methods advanced to accomplish the same objective. This, to the writer, is more important than the actual number recommending specific approaches. It is obvious that the fitting techniques for corneal lenses are still in a very fluid state, and that it will be some time before fitting approaches will demonstrate a greater degree of uniformity. Methods, no doubt, will be advanced in the future, which will make many of the approaches covered in this survey obsolete. As far as the present is concerned, however, it is hoped that the results of this survey will help to organize and crystallize the thoughts of those currently engaged in this field.

ANNOUNCEMENT

UNIVERSITY OF HOUSTON—THE CHILD IN OPTOMETRIC PRACTICE

Every phase of the visual care of children will be discussed at the Fall Postgraduate Conference, to be held at the University of Houston College of Optometry, November 6-7. The theme of the conference will be "The Child in the Optometric Practice," and included in the list of lecturers will be Dr. Nelson Greeman, Jr., Dr. Bernard Mazow, Dr. Murray Klaff, Mrs. Elizabeth MacNaughton and Mr. Bob Carrick, director of the Houston Center for Blind children. The Fellowship Dinner, to be held Sunday evening, will be followed by a panel discussion on the "Role of the Optometrist in Developmental Vision Testing," with all lecturers participating. Registration fees will be $20 for optometrists and $5 for their wives, a ticket to the Fellowship Dinner being included in the registration fee in either case. For registration, room reservations, write to College of Optometry, University of Houston, Houston 4, Texas.

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DICTIONARY OF VISUAL SCIENCE

In 1948 Drs. Max Schapero and David Cline began work as a post-graduate thesis on a word-list defining certain terms used uniquely in the field of optometry. As the work progressed, they became convinced of the need for a dictionary covering the broad field of visual science. Their first estimate of the time such a compilation would require was two years! In 1950 Dr. H. W. Hofstetter joined in the work as one of the editors. From this modest beginning and *twelve* years later (more than half the time it took Noah Webster to prepare the first edition of his Dictionary of the English language) has come the *Dictionary of Visual Science*, published by the Chilton Company.

This Dictionary is an immensely significant contribution to the field of optometry and to the whole field of visual science. The editors and their 61 collaborators have carefully and exactly defined over 13,000 terms embracing 27 aspects of the subject. The collaborators include

recognized authorities representing all of the professions related to vision, including physiology, optics, ophthalmology, neurology, illuminating engineering, dispensing opticianry, and psychology, as well as optometry. The format is attractive, the type-face well-chosen, and the quality of paper good. The definitions are comprehensive and meaningful. The broad coverage eliminates the need of consulting numerous reference tools when seeking a ready, exact definition of a term in the visual sciences.

As an optometric librarian,* I have long felt the need of just such a Dictionary and a Technical Assistant on the *Dictionary of Visual Science* for the past four years. I have had an opportunity to test it on many occasions when it was still in manuscript form. Based on this experience, I unhesitatingly recommend it.

Members of the American Academy of Optometry can take pride in the fact that all of the editors and many of the collaborators of this book are from their ranks. Moreover, the Academy granted some of the funds to defray the costs of manuscript preparation. Additional grants for this purpose were also made by the Southern California Chapter of the Academy, the American Optometric Foundation, and the Los Angeles College of Optometry.

Dictionary of Visual Science. Edited by Max Schapero, David Cline, and Henry William Hofstetter. Chilton Company, Book Division, 56th and Chestnut Sts., Philadelphia 39, Pa. 1960. 785 pages. Illustrated. $15.

*Los Angeles College of Optometry

GRACE WEINER

CURRENT COMMENTS

Terry Judith Parkins
Editorial Assistant

Optometrists will confer a favor by sending news items of general interest for this department: such as relate to new instruments, clinical techniques, education, visual health and optometric legislation and organizat on.

BVI STARTS NEW PUBIC RELATIONS CAMPAIGN

The Better Vision Institute, with the full support of the Optical Manufacturers Association, is now undertaking a splendid new public relations campaign. Its aim is to make the public aware of the need for professional eye examinations and refractions. The main effort will be concentrated in television and full page advertisements in LIFE magazine. TV is used to establish the identity of BVI and to get the message in

the public mind. The printed ads will back this up with strong impact. This program is directed to the individuals who need visual care but do not have it and to those who have spectacles and now need them changed. By educating this vast group, estimated at 50 million individuals, to this genuine but unrecognized need BVI and the OMA are performing an important public service and one of value to all optometrists.

Individually all optometrists should support this activity by joining the Better Vision Institute. The annual dues are $12 for an optometric office with the doctor and his assistant on duty. If more than two persons are on duty the dues are $6 additional for each individual over two. For example, an office with two optometrists, an orthoptist, a girl dispenser in charge of the style room and an office secretary, the dues would be $30 for 1961. A letter of application accompanied by check should be sent to the Better Vision Institute, 230 Park Avenue, New York 17, New York. Join BVI today. Full optometric support of this outstanding public relations campaign by all optometrists will make the work of the BVI more effective and of greater value to us all.

THE CHALLENGE OF THE CONTACT LENS

At the close of a recent successful CLAO meeting Dr. John R. Kennedy, St. Paul, said, "We have had a splendid conference and convention. For a moment I would like to reflect on the great new promise that stands before us. The challenge of the contact lens. There has been much written on the subject of contact lenses. How to provide them for our patients. How to adjust them. How to modify them. But the really interesting and great thing that must come is our own proper concept of how to handle this field. Contact lenses are not the next logical development from spectacles. The modern contact lens has leaped over years of evolution and projected each of us into a new era of eye care. This is our own missile age and we are now learning how to control it. Some have learned more than others but eventually all will possess the basic knowledge that turns frustration into organization and organization into productive dependable results.

"There is an old Chinese curse that says, *May You Live in Interesting Times*—knowing full well that this means change, surprise, pressure, competition and tension. This curse is upon all of us. We do live in interesting times and we will for all our days. The twentieth century has shown that man can rise from the gruelling problem of just striving for existence to a more important search for a better way of life of which contact lenses are a part.

"We must not resist this change that now comes into our professional lives. On the other hand we should welcome it for it is part of the better way and but a new form of what we already know and do for our patients. The problems of life do not disappear but they just change. They become more interesting in the realization of the opportunities that are offered to us as well as in the full and profound meaning of that Chinese curse which I now rephrase to admonish you. *May You Enjoy Living in These Interesting Times.*"

DR. CHARLES R. STEWART RESIGNS

Dr. Charles R. Stewart has announced his resignation as dean of the College of Optometry of the University of Houston to enter private practice in Waco. The resignation is effective February 1, 1961.

Dean Stewart has purchased the practice of the late Dr. Stanley R. Block in Waco, Texas, effective October 1. Dr. James S. Holt, a 1958 graduate of the University of Houston, is associated with Dr. Stewart in the Waco office.

In a statement released September 24, Dr. Stewart declared that he is leaving the University to enter private practice and to realize long-time desires to live in a smaller city and to spend more time at home with his family.

Lt. General A. D. Bruce, chancellor of the University, accepted the resignation with regret. "For many years," the chancellor said, "Dean Stewart has diligently and devotedly served optometry as Dean of the University of Houston College of Optometry. Under his leadership, the College has grown rapidly in enrollment and in service to the public and to the profession of optometry. His personal decision to continue the private practice of our loyal and devoted friend, the late Dr. Stanley R. Block, is understandable. This is particularly true for those who are aware of the many week-ends and long hours which he has given to the College, and the many attractions which private practice has to offer.

"We will continue to enjoy Dr. Stewart's leadership until the beginning of the Spring semester. We will not be hurried in selecting his successor, but we fully expect that the optometry faculty will carry on with an outstanding educational program in which all optometry can be proud while a suitable replacement is sought."

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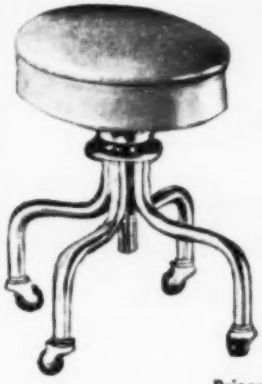

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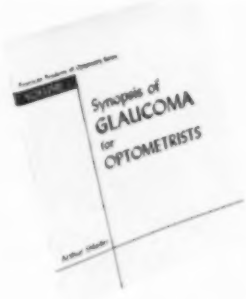

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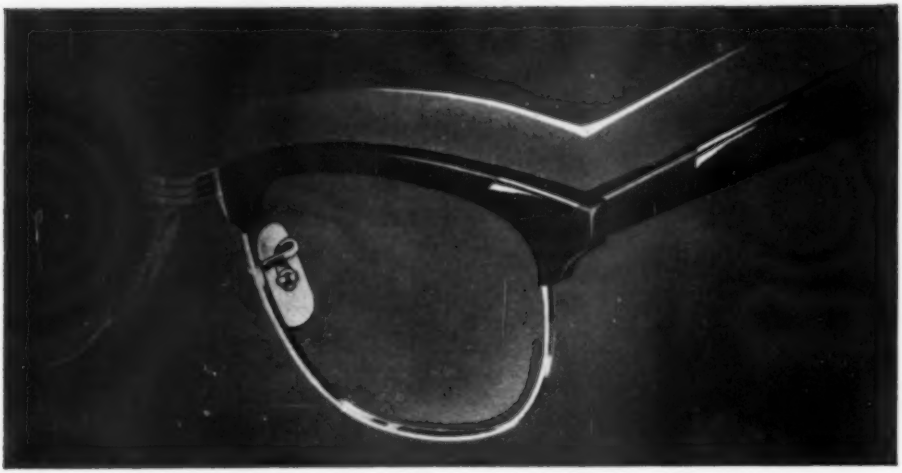

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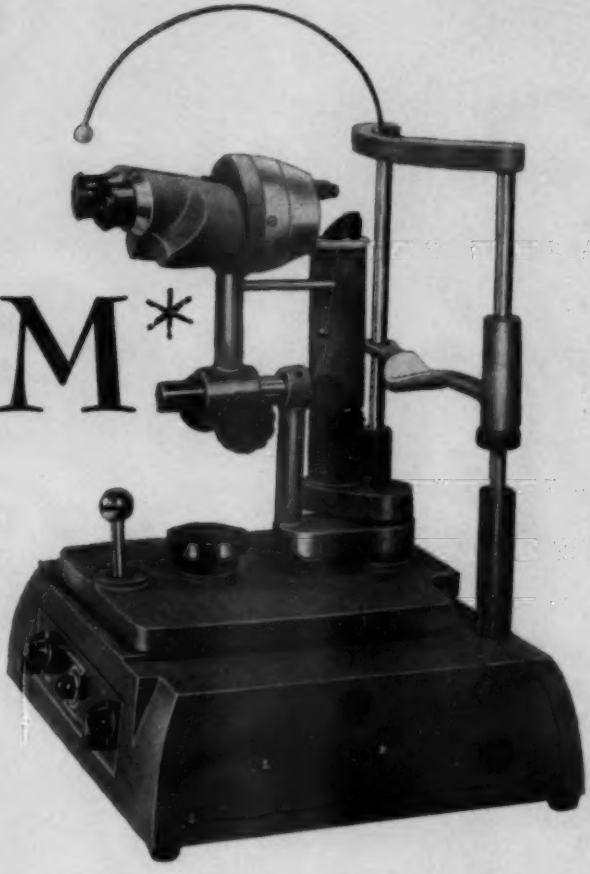

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